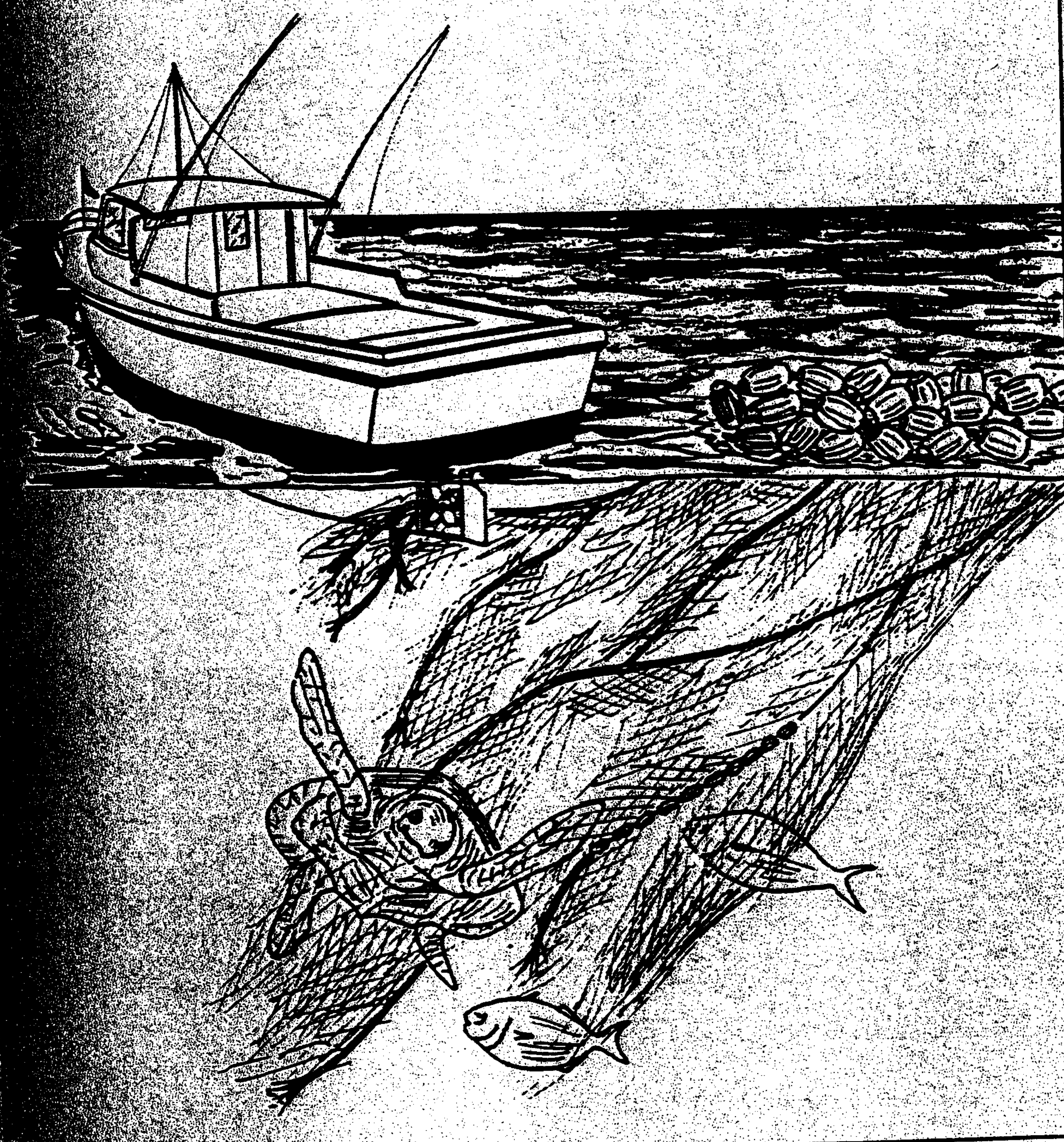
SESSION I

SOURCE AND QUANTIFICATION OF MARINE DEBRIS



THE TYPES AND ESTIMATED AMOUNTS OF FISH NET DEPLOYED IN THE NORTH PACIFIC

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ABSTRACT

This report reviews the major net fisheries of the North Pacific and provides crude estimates of the amount of net gear available to the various coastal and high seas fisheries. Specifications of gill nets, purse seines, trawls, set nets, haul seines, and lift nets, when available, are provided, together with the number of units of nets and vessels operating in the fisheries. First-cut estimates indicate that there are about 170,000 km of gill net, 2,000 km of purse seine, 5,500 km of trawl net, and 8,900 km of miscellaneous net gear available to the various North Pacific net fisheries.

INTRODUCTION

The modern fishing industry has developed primarily as a result of three technological revolutions--mechanization, echo sounding, and development of synthetic fibers (Kristjonsson 1959).

The advent of synthetic fibers brought about a major revolution in the fishing industry. Nylon, the first of the synthetic fibers to be developed, had wide applications in fishing nets. Made from polyhexamethylene adipamide, nylon, and other amides such as perlon and rilsan all possessed excellent characteristics for constructing the ideal fish net (Arzano 1959; Lonsdale 1959).

Nets made from nylon and all other synthetic fibers, eventually lose strength in use; however, they do not rot. It is this nondegradable quality that makes nylon nets so highly attractive to the fishing industry as well as a menace when they become a component of the marine debris.

This report reviews the major net fisheries of the North Pacific (Fig. 1) and makes an attempt at providing some measure of the amount of netting used in coastal and high seas fisheries. It is by no means an exhaustive review and excludes many of the minor net fisheries operating along coastal areas of North Pacific rim countries. Reviews of the net fisheries are gear-oriented; however, because there are many areas of overlap in gear types for any given species, the net gear that contributes most heavily to

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In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

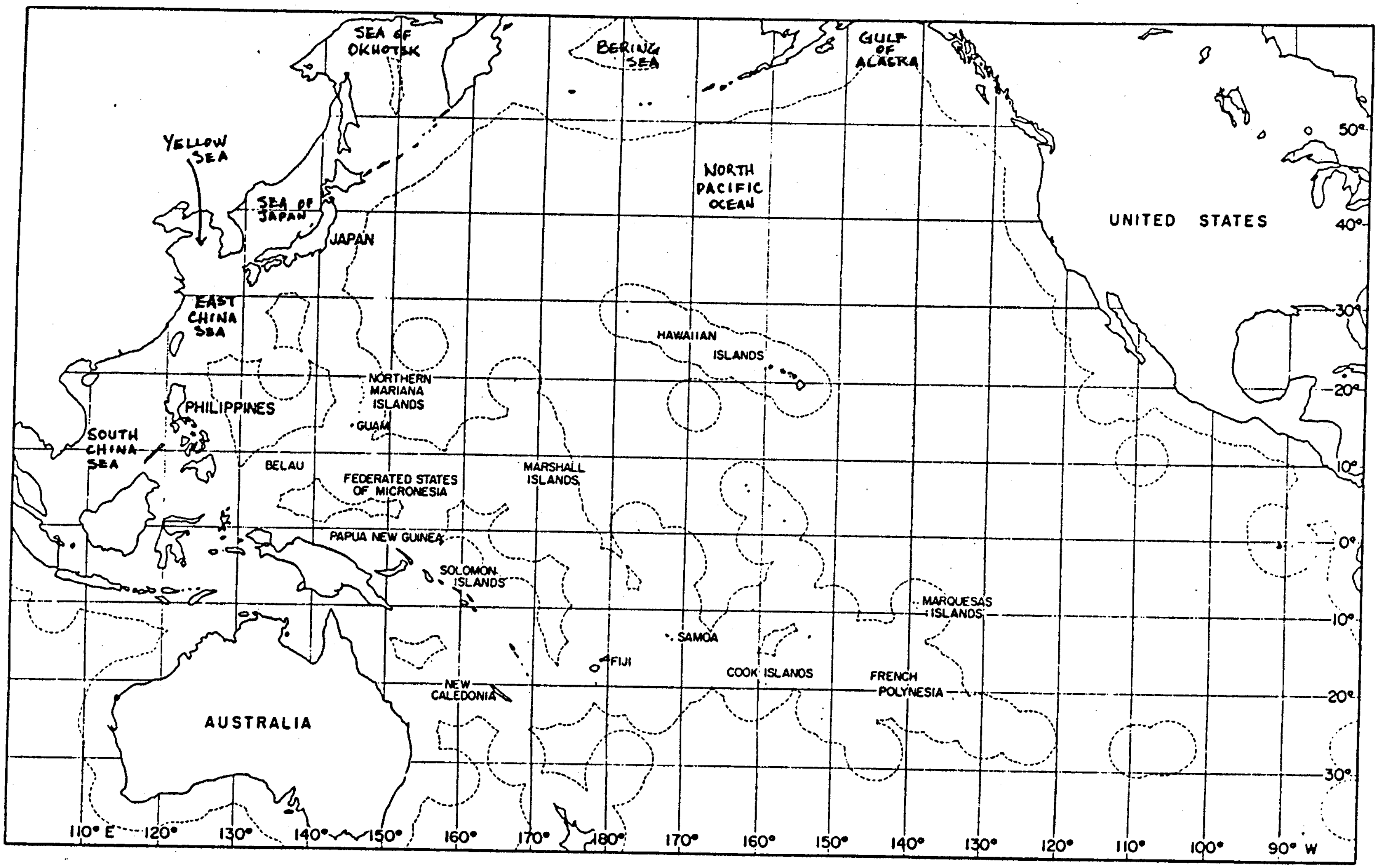

Figure 1.--The North Pacific Ocean.

harvesting the species will be the one emphasized. When available, the gear specifications, as well as the number of vessels operating, and the number of units fished per vessel are provided. Scientific names of species mentioned in this report are given in tables either in the text or appendix.

Although this report describes "typical" gear, it should be obvious to the reader that fishing gear, like fishing methods, are different throughout the world. Differences in the gear used, even for catching the same species and in the same fisheries, exist because fishermen tend to adapt or modify gear based on their experience, knowledge of the fish's habitat and behavior patterns, and cultural practices.

NET CHARACTERISTICS

Netting, which is basically constructed of yarns or threads to form meshes, can be fabricated by machine or by hand in any size desirable, in whatever type and size of twine, and can be either knotted or knotless.

Before synthetic fibers came into general use, most twine used to fabricate webbing came from natural fibers such as cotton, linen, hemp, manila, and sisal. Synthetic fibers first appeared in Japanese gill nets and in portions of surrounding nets in 1949 with the introduction of nylon webbing. In 1951, vinylon (polyvinyl alcohol) was used in surround nets and later vinylidene was used in large set nets (Japan Chemical Fibres Association (JCFA) 1971). The production of synthetic fiber fishing nets increased annually, and by 1956 it surpassed production of nets made of natural fibers. By 1957, synthetic fiber nets accounted for 70% of the production, and by 1964, 100% of all netting material made in Japan.

Additional synthetic fibers such as vinyl chloride, polyethylene, polyester, and polypropylene were introduced subsequently for fishing nets that required specific properties. The downward trend in the production of natural fiber nets and the upward trend in the production of synthetic fiber nets in Japan in 1960-68 are illustrated in Table 1; the percentage of the various types of nets made of the different synthetic materials is given in Table 2.

Table 1.--Fishing net production in Japan (Japan Chemical Fibres Association 1971). (Source: Ministry of International Trade and Industry, Japan.)

Year	Grand total	Natural fiber nets total	Synthetic fiber nets total	Breakdown by fiber						
				Polyamide	Polyvinyl alcohol	Vinylidene	Polyvinyl chloride	Polyester	Poly-ethylene	Poly-propylene
1960	10,596	2,344	8,252	3,639	3,194	709	528	93	99	
1961	11,295	2,006	9,289	4,134	3,567	715	409	167	297	
1962	11,732	1,346	10,386	4,726	4,040	509	364	187	560	
1963	12,965	1,061	11,904	6,976	2,320	689	448	416	967	88
1964	14,015	746	13,269	6,874	2,939	845	310	559	1,556	186
1965	16,236	567	15,669	8,944	3,345	827	279	482	1,715	77
1966	17,773	400	15,373	9,566	3,514	844	205	581	2,591	72
1967	18,765	381	18,384	10,283	2,933	869	183	407	3,569	150
1968	18,983	366	18,647	9,414	3,667	1,098	87	587	3,507	287

The following definitions are from Klust (1973), Nomura and Yamazaki (1975), and McNeely and Walsh (1980).

Breast line.--Vertical ropes which connect at each end to the footrope and headrope. Breast lines are attached to side panels of trawl gear and to the ends of purse seines and gill nets.

Bunt, sack, bag.--These terms refer to the heavy web section of purse seines into which fish are concentrated by sequentially strapping aboard sections of the bunt to dry up the fish before they are scooped aboard in a large scoop called a brail.

Cod end, bag, sack, fish bag.--These terms are used to describe the heavy mesh in the aftermost sections of trawl gear where fish accumulate during the fishing operation. Some larger vessels drag the entire cod end up an inclined ramp at the stern of the vessel, and smaller vessels are required to split the catch into smaller amounts that can be brought aboard in increments up to 3 tons per hoist.

Extensibility.--The complex physical properties of netting that undergo changes in dimension in the form of elongation or extension due to application of a tensile force. The complexity results from several factors which include but are not restricted to the amount of elongation immediately after applying a breaking load, reaction of the yarn to a gradually increasing load, reaction under sustained load over long durations, reaction of yarn to repeated loading and unloading, total or permanent elongation, and energy absorption.

Footrope, leadline, groundline.--A lower section of the net to which weights (lead or chains) are normally attached. The term "groundline" is sometimes also used in describing the low leg of bridles used to pull a trawl through the water. A footrope provides downward thrust to oppose upward thrust of the float line to facilitate opening of the net in fishing operations.

Hanging ratio.--Defined as L/W, i.e., the relationship between the length (L) of the rope along which the webbing (W) is hung and the stretched length of the webbing. For example, 628 m of stretched webbing hung on 440 m of rope will produce a hanging ratio of L/W = 440/628 = 0.71.

Hang-in.--An expression also quite commonly used and defined as (W-L)/W.

Headrope, float line, corkline.--These terms are used interchangeably to describe the top strength member rope and its floats which are normally attached to assist in vertical opening of the net.

Intermediate.--Intermediate sections of the net are found only in trawl gear in the after-section of the net and are used to connect the main body meshes to meshes of the fish bag.

Main body or body.--Refers to the great bulk of netting used to fill in the basic design of the net, exclusive of peripheral parts such as riblines, headrope, footrope, breastlines, selvage strips, intermediate sections, and fish bag.

Net.--Any completed assembly of netting or sections of netting having a prescribed shape useful to perform a desired function, e.g., tennis net, safety net, basketball hoop net, and fishing net.

Netting, webbing, web.--These three terms are used interchangeably to describe the basic material from which nets are made.

Panel.--A single section of netting cut to a prescribed shape and size that is joined to other panels in the construction of a completed net.

Riblines.--Strength member ropes attached to outer seams of trawl gear. Whenever netting attached to riblines is hung in (unit length of netting attached to less than one unit length of ribline), it becomes a load-bearing member during fishing operations and assists in opening the net to its desired shape. Whenever netting is hung to riblines with identical unit lengths, the riblines serve only to limit the extent of damage whenever a net is torn and to assist in bringing aboard large catches of fish after the net has been collapsed during retrieval.

Selvage (selfage) edges and selvage strips.--The machine-made or man-made, double twine edges along a length of netting or along the edges of panels of netting. Selvage strips are narrow sections of netting fabricated of much heavier twine than main body netting and have a width of 2 or 3, up to 50 meshes. Selvage strips are commonly made utilizing larger mesh size in addition to larger twine size. Their main function is to more equally distribute load among strength-bearing members such as headropes, footropes, breastlines, and riblines, to main body meshes.

Splitting strap.--Heavy ropes which are permanently threaded through a maximum of seven steel rings placed around the cod end to allow pinching off a part (one-half to 3 tons) of the catch. Splitting straps are utilized by small vessels to bring aboard small sections of large catches.

NET CLASSIFICATION

The following brief descriptions of the various types of net gear used in fishing were adapted from Nomura and Yamazaki (1975).

I. Gill Nets

A. Surface gill net.--Buoyed to float on the surface.

1. Fixed surface gill net.--One or both ends of the net are anchored; used in shallow inlets or narrow waterways where fish such as sardine migrate.

2. Drift surface gill net.--Net drifts with current; used mainly in open offshore waters; for night sets, lights are attached to ends of nets; used in the salmon gill net fishery.

B. Midwater gill net.--Nets are suspended in midwater by long float lines.

1. Fixed midwater gill net.--Construction same as fixed surface gill nets; fishing depth is adjusted by use of long float line; ends of net anchored.

2. Drift midwater gill net.--Same as drift surface gill net; fishing depth adjusted with long float line; used to capture sardine, mackerel, and saury.

C. Bottom gill net.--Nets set near or on bottom; used for catching cod, flounder, shark, mackerel, sea bream, shrimp, and crab.

1. Fixed bottom gill net.--Set on or near the bottom with anchors; effective fishing depth to 200 m.

2. Drift bottom gill net.--Net allowed to drift freely over sea bottom.

D. Encircling gill net.--Gill net, which is set inside a large encircling net to first encircle the fish school; the inner net gills the fish, used to catch young yellowtail.

E. Sweeping gill net.--A net in which one end is anchored and the other other end is towed in a circle to bring the net in contact with fish.

F. Entangling net.

1. Single entangling net.--Single net with or without leadline used to entangle fish; used for king crab and tuna.

2. Trammel net.--A net composed of a panel of small meshed webbing sandwiched between two outer panels of large-meshed webbing; used to entangle or trap fish in a loop of webbing.

II. Haul Nets

A. Beach seine.--A bag-shaped net with long wings; usually used along shoreline and pulled by hand toward the beach.

B. Boat drag seine.

1. Upper-layer drag net.--This net is a long, conical bag with wings.

2. Danish seine.--A net in which one end is first attached to a buoy underwater before setting; remainder of tow rope, net, and opposite side tow rope is then payed out as boat travels a triangular course to return to the buoy; buoy is retrieved and the two ropes are hauled by the boat thus bringing the wings closer together and driving the fish into the net mouth.

3. Trawl net.--Conical net pulled by one or two boats for set periods of time.

a. Bottom trawl.--Hauled on or just off the bottom.

(1) Beam trawl.--Uses beam or other devices to spread net mouth; examples are dredge and coral net.

(2) Otter trawl.--Uses otter boards or "doors" to spread net mouth; examples are bottom fish trawl and shrimp trawl.

(3) Two-boat trawl.--Uses two boats to spread net mouth; examples are bull trawl and paranzella net.

b. Midwater trawl.--Hauled in midlayers; mouth held open either by otter boards or by two boats.

III. Push Net

Triangular, bag-shaped net two sides of which are fixed to scissorlike crossed bamboo sticks; net is pushed forward in shallow water by hand or boat.

IV. Lift Net

Operation of net involves raising or hauling a submerged net upward out of the water; net can be a small hand-operated net, hoop net, blanket net, or a large mechanical lift net.

A. Floating lift net.

1. Stick-held lift net.--Net is set deep beneath the water surface and is allowed to flow freely from the boat; hauling lines are attached to keep the net from drifting away; submerged net is lifted upward when fish schools aggregate over net; used to catch saury, mackerel, and horse mackerel with the aid of light attraction.

2. One-boat lift net.--Small scooping net is used.

3. Eight-angle net.--Net is a lift net operated by two boats.

B. Bottom lift net.--Net is submerged and rests on bottom.

1. Four-angle dip net.

2. Three-boat lift net.

3. Four-boat lift net.

4. Eight-boat lift net.

V. Surrounding Net

Net used to encircle fish schools from the side as well as the bottom; net is rectangular or has a bag with wings thus resembling a haul seine.

A. Surrounding net with pocket.--A semisurrounding net; bag net (better referred to as a lift net) is used together with a pair of wing nets; used at night with lights to attract fish schools.

B. Surrounding net without pocket.

1. Surrounding net with purse line.--Net is set around a fish school and the purse line quickly pulled in to close off the bottom of the net.

a. One-boat purse seine.--Net is set after skiff holding one end of the net is launched; boat then pays out net to surround fish school; the seiner then retrieves purse line and bridle from the skiff and the net bottom is closed; net is hauled with a power block; example: tuna purse seine.

b. Two-boat purse seine.--The purse line or wire rope is attached to the sinkers, similar to the one-boat seine; net operated by two boats; two-boat seine differs from one-boat seine in twine size, mesh size, length, width, and length-width ratio.

2. Surrounding net without purse line.--Lampara-type net; has neither rings nor purse line along the bottom.

VI. Cover Net

A. Cast net.--Conical net thrown by hand so that it opens nearly flat as it falls on the water surface; net sinks rapidly due to weights attached to edge of net.

B. Lantern net.--Net is fabricated to cover a wooden, lantern-shaped frame; operates by covering fish; hand hauled.

VII. Trap Net

Fish are caught in collecting units from which escape is prevented by labyrinths and retarding devices such as gorges and funnels.

A. Large-scale trap net.

1. Large stationary net without traps.

a. Large stationary triangular net.--Gear consists of a leader net and main net.

b. Large stationary oblong or octagonal net.--Main net is 400 m long and 100 m wide; leader net is nearly 4,000 m long.

2. Stationary net with trap.--Net has three parts--bag net (or main net with bag), barrier net (or playground net), and leader net.

a. Stationary net with one trap.--Main net is 200 m long; used to catch yellowtail, horse mackerel, squid, and some pelagic species.

b. Stationary net with two traps.

B. Medium stationary trap net.

1. Sardine stationary net.--Bag net does not reach to bottom; has leader net and big playground net with bottom sloped upward.

2. Herring stationary net.--Net is box-type bag net.

3. Salmon stationary net.--A surface or bottom trap net used on grounds with swift currents.

C. Small-scale stationary trap net.--A pound net with main net, leader, and conical bag net.

D. Guiding barrier.--Screen labyrinth net; gear consists of a fence (or fences) which guides the fish to one or more retaining chambers.

E. Portable trap and stow net.

1. Covered pots and fyke net.--This gear can be used singly or arranged in systems with wings and leaders; net has basketlike or cagelike appearance; made of wood, netting, wire, or plastic.

2. Stow net.--Net is fixed on stakes or anchored with mouth kept open by frame; usually placed in strong river currents.

NET FISHERIES

The net is a relatively young invention and was probably introduced in hunting earlier than in fishing (von Brandt 1964). Although net fishing developed rapidly in some countries after its introduction, it was of secondary importance in others where fishing methods such as hook and line, traps, striking gear, shooting, and fish barriers were more highly developed (von Brandt 1964). But it seemed inevitable that net fishing would occupy a prominent part in the fisheries of many nations as net making technology was perfected by repeated trial and error over a long period. Even today, many nations have not acquired the knowledge and technical skills to make nets; however, this is no longer a problem since machine-made nets from major industrial and manufacturing nations can be delivered to the most remote places of the world.

Today, the net fisheries harvest a large number of species using a wide assortment of gear including gill nets, tangle nets, trawls, purse seines, set nets, lift nets, and haul seines. Excellent reviews of some of the major fisheries in the North Pacific may be found in a number of reports (Alverson et al. 1964; Chitwood 1969; Frey 1971; Takahashi 1972; Browning 1974; and Forrester et al. 1978, 1983).

In the sections that follow, some of the major net fisheries in the North Pacific are reviewed.

Gill Net Fisheries

In the chronology of net gear, the gill net evolved after the beach seine but well before the development of the purse seine (Browning 1974). In terms of tonnage of fish landed, however, the gill net has to rank behind the purse seine and the trawl.

Although resembling the beach seine, the gill net fishes on a different principle, that is, whereas a beach seine surrounds or closes off the path of a school of fish, the gill net is simply a wall of netting whose meshes either form a "noose" around the heads and bodies of fishes and molluscs that swim forward vigorously (von Brandt 1964; Browning 1974), or entangle legs and spines of crustaceans. Furthermore, the gill net is much more versatile because it can be fished at the surface, in midwater, or on the bottom and be anchored or set adrift.

Gill nets may be classified into several categories depending on geographic area. On the U.S. west coast and Alaska, gill nets may be classified into two broad categories--drift nets in their several forms and the set or anchored gill net (Browning 1974). In Japan, in addition to the two mentioned above, there is a third classification referred to as a "movable type" gill net in which the net is used to encircle or is set near fish schools and the fishermen actively drive or herd the school into the meshes of the net (Yamaha Motor Co. (Yamaha) 1979a).

There are a number of major and minor fisheries in the North Pacific in which fishing vessels use gill nets exclusively or in combination with other gear. These include fisheries for salmon, squid, tuna, barracuda, pomfret, saury, shark, white seabass, Pacific herring, yellowtail, mackerel, bonito, flyingfish, sardine, pollock, king crab, cod, bream, shrimp, and flatfish (Nomura and Yamazaki 1975).

A net much like the gill net is the trammel net. Trammel nets have two outer walls and an inner, longer sagging curtain. They are designed to prevent fish like halibut, which can swim powerfully in reverse, from freeing themselves from a standard gill net. A fish swimming into a trammel net entangles its head in the small mesh and drives the inner curtain through the outer wall. The mesh then collapses behind the fish, bagging it and blocking its escape (Pleschner 1983).

Because of the extra time and skill required in fishing with trammel nets, many halibut fishermen use a simpler suspended or "trammelized" gill net. This type of net is fabricated by taking a single-walled net and interweaving a vertical string or line at intervals to prevent the net from expanding to its full height. The added slack traps the fish in a bag of mesh. This adaptation to the gill net fishes cleaner and offers a little more protection from seal predation; however, it is not effective at catching large fish (Pleschner 1983).

Coastal Gill Net Fisheries

In Japanese net fisheries, although the number of boats that can be operated in fisheries such as small-scale trawling, purse seining, boat seining, and fixed net fishing is limited by a licensing system, the number of gill-netters is licensed only in certain prefectures; therefore, gill netting is a popular fishing method among coastal fisheries and provides support to many families that rely solely on income from fishing (Yamaha 1979a). In fact, of Japan's fleet of 328,000 fishing boats that are under 5 gross tons (GT), 38,000 or 12% use gill nets exclusively.

Fishing with gill nets is a relatively simple operation along the coasts of Japan. The small fishing boats operate close to shore and can set and retrieve nets with small crews (Yamaha 1979a). Major species taken include sardine, mackerel, horse mackerel, saury, skipjack tuna, yellowtail, bluefin tuna, swordfish, salmon, trout, cod, shark, sea bream, flatfish, octopus, squid, sea urchin, sea cucumber, shrimp, and crab.

In the coastal drift net fishery for salmon and trout along the northern half of Japan in the northwestern Pacific and in the Sea of Japan, 1,380 boats landed 34,218 metric tons (MT) to 73,769 MT of salmon in 1971-76, averaging 50,024 MT annually (International North Pacific Fisheries Commission (INPFC) 1979).

The type of gill net used in the coastal fisheries varies considerably, depending on the target species. The fishermen decide on the most appropriate design and construction of the net, taking into consideration the quality of the material, thickness of the thread, mesh size, knotting method, mesh depth, and color. They also must select an optimum hanging ratio of the netting to give the net flexibility and increased entangling efficiency (Yamaha 1979a). The hanging ratio is usually determined after taking into consideration the target species, bottom topography, tidal current, water depth, and the surplus buoyant force of the floats.

For sardine drift net, the mesh is 4.3 cm, the float line is 30-48 m with a 35-40% hang-in, and the leadline is about a meter longer than the float line. The boats in this fishery carry about 7-8 men and are about 20 GT. Each boat sets about 40 units of nets per set (Nomura and Yamazaki 1975).

The Spanish mackerel fishery uses a different net with a mesh size of 7.5 cm, a depth of 130 meshes, and a float line 26 m long. Because the net is intended to drift at the surface, the leadline, which is 25 m long, is without weights. The hang-in is 44.5% in the float line and 44.6% in the leadline (Nomura and Yamazaki 1975).

The gear used in the mackerel drift net fishery is similar to that used in the sardine drift net fishery except that the mesh size is 7.0-8.5 cm and depth varies widely from 200 to 500 mesh. The length per unit of net is 75 m and the hang-in is 30-40% (Nomura and Yamazaki 1975).

There is also a mackerel bottom gill net which has a mesh size of 7.6 cm, is 100-400 meshes deep, with a float line of 36.4 m and a leadline of 33.3 m. The hang-in is 30% (Nomura and Yamazaki 1975).

In the flyingfish drift net fishery, the gear is fabricated into three parts--the end net, the first leader net, and the second leader net. Thirty units of net are strung together to form a length of gill net stretching 1,047 m long (Nomura and Yamazaki 1975).

Still another gear used in the coastal fisheries is the shrimp bottom gill net (Nomura and Yamazaki 1975; Yamaha 1979a). Made of nylon webbing, the mesh is 6-10 cm and the net is 10-17 meshes deep with a 50-69% hang-in. Each unit is 2.5 m long.

For shark fishing, a bottom gill net with mesh sizes 17-25 cm is used, and because sharks are caught by trammeling, the hang-in is as large as 40%. The net is 18 meshes deep with a stretched length of 50.5 m hung on a float line of 37.9 m. The leadline is 30.3 m. The boats operating in this fishery are 7-10 GT with eight men aboard. Usually, each vessel sets 40-80 units of gill net per day.

The Soviet Union's coastal fisheries bordering the North Pacific involve traps, beach seines, and weirs to capture maturing salmon from schools that are migrating to the spawning grounds. The areas fished include the east and west coasts of Kamchatka, the northern part of the Okhotsk Sea, along the coastline bordering the Okhotsk Sea from Lisyansky Peninsula to the Amur area, Amur River basin north to the Iska River, coast of Primore, Sakhalin, Kuril Islands, and the Gulf of Anadyr (Fig. 2) (INPFC 1979).

Soviet fishermen use several different types of gill nets and tangle nets for fishing in the northwestern Pacific. In general, nets are 20-30 m long, but for certain types of fishing, e.g., deep bottom fishing, nets may be up to 1,000 m long. The depth of the net is dictated by the target species. Most set gill nets are 1.7-2.5 m deep; most drift nets are 6-15 m deep. Andreev (1966) described several nets used in the northwestern Pacific, as follows:

<u>Shark anchored gill net</u>.--The net is 25 m long and 25 meshes deep; hanging ratio is 0.50; mesh size is 80 mm; and twine size is 20/12.[2]

<u>Walleye pollock gill net</u>.--The net is 30 m long and 30 meshes deep; hanging ratio is 0.60; mesh size is 48 mm; and twine size is 18/3.

<u>Crab anchored gill net</u>.--The net is 46 m at the corkline and 42 m at the leadline; the depth is 6.5 meshes; hanging ratio is 0.42-0.46; and the twine size is 20.12. No mesh size is given.

<u>Anchovy drift net</u>.--The net is 45 m long and 200 meshes deep; hanging ratio is 0.60; mesh size is 14 mm; and the twine size is 130/6.

<u>Pacific saury drift net</u>.--The net is 36 m long and 5.1 m deep; hanging ratio is 0.60; mesh size is 16 mm; and twine size is 61/6.

<u>Mackerel drift net</u>.--The net is 30 m long and 6.4 m deep; hanging ratio is 0.60; the mesh size is 40 mm; twine size is 34/12.

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[2]The numerator is the size of the yarn with which the twine is constructed and the denominator is the number of yarns in the twine.

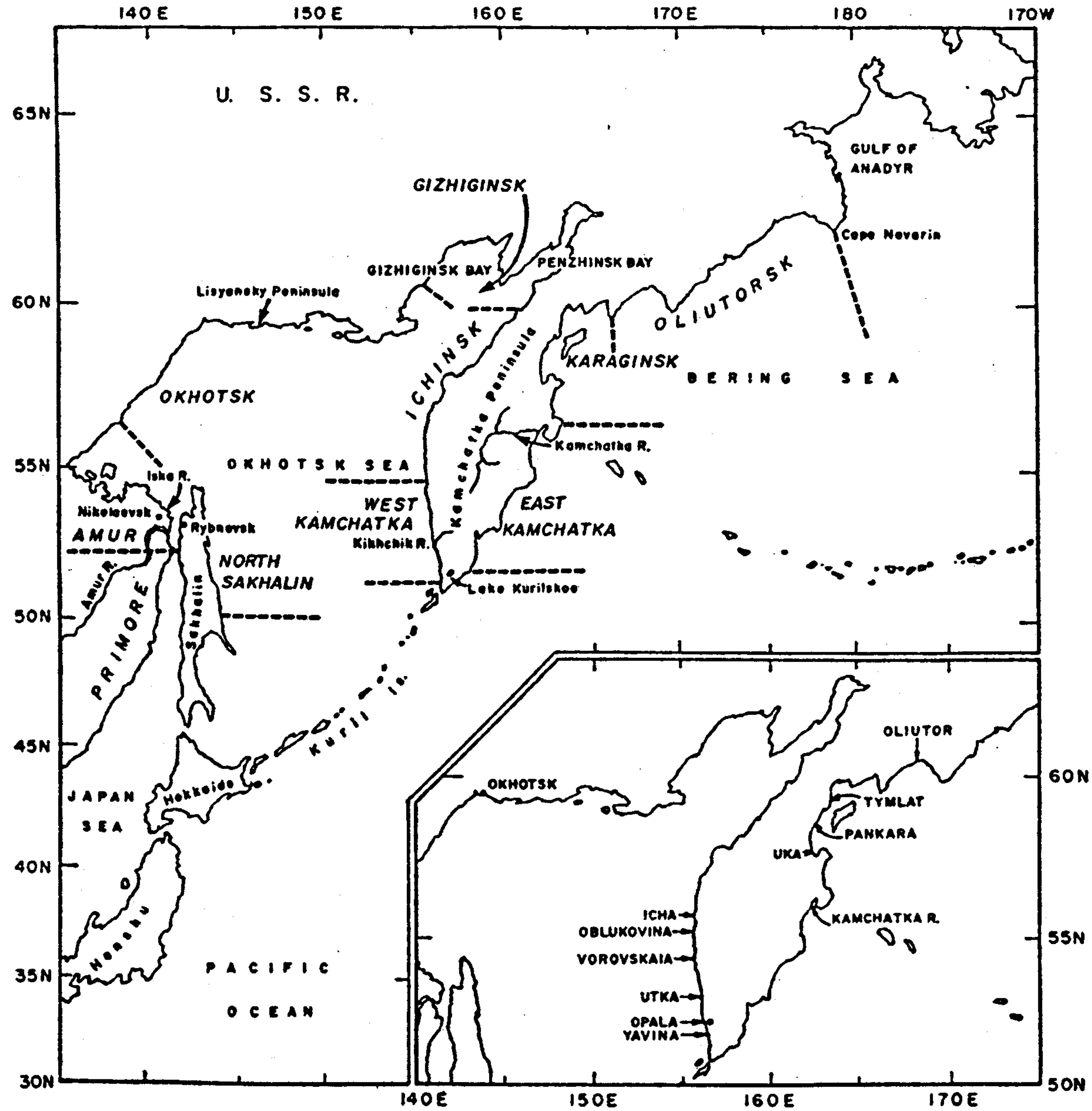

Figure 2.--Areas fished for salmon by Soviet fishermen (International North Pacific Fisheries Commission 1979).

Salmon drift net.--The net is 30 m long and 3.3 m deep; hanging ratio is 0.60; twine size is 34/12. No mesh size given.

Herring drift net.--The net is 30 m long and 6.0 to 15.2 m deep; hanging ratio is 0.60; twine size is from 34/6 to 61/6. No mesh size given.

Information is lacking on the number of units of gear used in the various Soviet fisheries.

Canadian and United States fishermen, including those in Alaska, fish for salmon in inshore waters. Salmon fishing with nets is prohibited at any distance from the outer coast with minor exceptions. Thus, except for salmon taken by trolling, the bulk of the Canadian and United States catch comes from purse seines and gill nets fished in inshore waters.

The Canadian gill net fishery for salmon in Georgia Strait is largest in the Fraser River area where fleet size reaches 800 vessels during the summer fisheries for sockeye and pink salmon, and during occasional fall openings for chum salmon (Argue et al. 1983). In the remainder of Georgia Strait, there are perhaps 3,000 gill net boats that fish at least once. The boats in this fishery are 10-15 m and carry nets with meshes of 130-149 mm for sockeye, pink, and coho salmon and 165-216 mm for chum and chinook salmon. Nets are restricted to a length range of 137 to 336 m and a depth of no more than 60 meshes. The number of days allowed for net fishing varies widely depending on location of the fishing grounds. In 1981, 2,508 gill-netters and combination gill net-troll boats fished for pink, chum, and sockeye salmon in British Columbia waters (Beacham 1984a, 1984b, 1984c).

A Canadian skiff gill net fishery also exists for high value roe herring (Ness 1977a; Forrester et al. 1983). In this fishery, gill nets now account for about half of the herring roe catch (Hourston and Haegele 1980). These gill nets are fished from aluminum skiffs especially developed for this fishery. In 1978-79, 1,300 gill-netters fished for herring roe.

In waters off the U.S. Pacific coast states, the gill net is the most important commercial salmon gear, accounting for roughly 50% of the landings from these states in 1975 (U.S. Department of Commerce 1978). Following gill nets in order of importance was the purse seine which accounted for 35% of the salmon landings, whereas lines produced just 14%. The remaining 1% of the catch came from haul seines, otter trawls, pound nets, floating traps, pots, dip nets, reef nets, and wheels. A summary of operating units for the U.S. Pacific coast fisheries in 1975 is shown in Table 3.

In the early years of the salmon fishery, linen gill nets were used; however, nylon webbing was introduced in the 1950's and replaced linen rapidly. Monofilament nylon webbing was used by a few fishermen in 1958 but was banned in Washington and Oregon in 1959 and in Alaska in 1960. The ban on monofilament gear, however, was not applied to Indian fisheries in Washington and in the Columbia River where existing fisheries commonly used monofilament gill nets. In 1965, a multiple strand monofilament gill net was introduced in Washington and is legal gear at the present time.

Although the U.S. commercial salmon fishery operates in the four Pacific coast states, only Alaska and Washington have large net fisheries. The regulations concerned with the Alaska salmon fishery are extremely complex and involve variations, by statistical districts, in fishing season, gear specifications, and type of gear allowed (Table 4).

In Washington, the commercial salmon fishery, which is carried out in Puget Sound, Grays Harbor, Willapa Bay, Columbia River, and offshore, depends primarily on purse seines and drift nets. In Puget Sound, drift nets may be 549 m long with stretched mesh varying from 114 to 210 mm, depending on area, season, and target species. Around San Juan Island, some reef nets are also used. The season extends from May to October. At Grays Harbor and Willapa Bay, drift nets allowed are 457 m long with a minimum mesh size 127 mm. The season here runs from July through November (INPFC 1979).

Table 3.--Summary of operating units, 1975 (U.S. Department of Commerce 1978).

ITEM	ALASKA	WASHINGTON	OREGON	CALIFORNIA	TOTAL, EXCLUSIVE OF DUPLICATION
	NUMBER				
FISHERMEN:					
ON VESSELS	8,946	5,227	2,858	8,912	22,741
ON BOATS AND SHORE:					
FULL-TIME	7,067	5,278	1,628	7,769	21,742
PART-TIME	-	339	18	-	357
TOTAL	16,013	10,844	4,504	16,681	44,840
VESSELS, MOTOR	2,432	2,390	1,300	2,326	7,031
GROSS TONNAGE	83,349	60,868	37,727	137,486	269,413
BOATS:					
MOTOR	4,195	4,505	1,571	2,832	12,972
OTHER	-	-	-	364	364
GEAR:					
HAUL SEINES, COMMON	9	85	5	11	110
PURSE SEINES:					
ANCHOVY	-	-	-	9	9
HERRING	-	31	-	-	31
MACKEREL	-	-	-	43	43
SALMON	1,014	348	-	-	1,231
TUNA	-	-	3	138	141
OTHER	-	-	-	204	204
LAMPARA NETS:					
MACKEREL	-	-	-	23	23
SQUID	-	-	-	28	28
TUNA	-	-	-	6	6
OTHER	-	-	-	57	57
BEAM TRAWLS, SHRIMP	27	7	-	3	37
OTTER TRAWLS:					
FISH	20	97	143	533	778
SHRIMP	87	48	164	51	322
OTHER	-	1	-	-	1
POUND NETS, FISH	2	1	-	-	3
FLOATING TRAPS	8	-	-	-	8
POTS AND TRAPS:					
CRAB:					
DUNGENESS	27,799	36,378	57,683	39,793	157,250
KING	51,791	-	-	-	51,791
OTHER	37,274	-	-	-	37,274
CRAWFISH	-	250	150	4,200	4,600
FISH	-	825	6,050	8,515	15,325
LOBSTER, SPINY	-	-	-	9,900	9,900
OCTOPUS	-	570	-	-	570
SHRIMP	3,775	2,650	-	148	6,573
GILL NETS:					
ANCHOR, SET, OR STAKE:					
SALMON	2,361	680	4	-	3,045
OTHER	23	-	29	324	376
DRIFT:					
BARRACUDA	-	-	-	76	76
SALMON	2,677	2,218	325	-	5,113
SEA BASS	-	-	-	56	56
SHAD	-	-	56	-	56
OTHER	-	5	17	648	670
TRAMMEL NETS	-	-	-	35	35
LINES:					
HAND AND TROLL, TUNA	-	-	7,710	-	7,710
HAND:					
ROCKFISH	-	154	-	30	184
TUNA:					
ALBACORE	-	222	-	1,179	1,260
YELLOWFIN	-	-	-	540	540
OTHER	-	-	-	16,394	16,394
TROLL:					
SALMON	7,076	13,681	13,014	13,895	45,499
TUNA	-	6,010	1,040	6,088	12,378
OTHER	-	123	-	12,762	12,885
LONG OR SET WITH HOOKS	10,923	1,019	225	1,640	13,632
DIP NETS:					
COMMON	-	188	5	120	313
DROP	-	20	-	-	20
BRAIL OR SCOOP NETS	-	-	-	75	75
REEF NET	-	78	-	-	78
HARPOONS:					
SWORDFISH	-	-	-	193	193
OTHER	-	-	-	3	3
WATER PUMP	-	-	4	-	4
DREDGES:					
CLAM	-	4	-	-	4
OYSTER:					
COMMON	-	46	4	-	50
SUCTION	-	2	-	-	2
SCALLOP, SEA	3	-	-	-	3
RAKES, OYSTER	-	-	-	46	46
SHOVELS	23	125	52	-	200
DIVING OUTFITS:					
ABALONE	-	-	-	288	288
OTHER	-	-	-	168	168

Note: Haul seines in Alaska have been included with purse seines. Nets or lines made up of small units for ease in handling, but fastened together in fishing, are counted as a single unit.

Table 4.--Net regulations in the Alaska salmon fishery, by type of gear and statistical districts (International North Pacific Fisheries Commission 1979).

District	Legal gear: Drift net (m)	Legal gear: Set gill net (m)	Minimum stretch mesh (mm)	Beach seines, traditional and hand-hauled purse seines (m)
Arctic-Yukon-Kuskokwim	91	183-274	203 (June) 152 (other months)	--
Bristol Bay	274	91	137	--
Alaska Peninsula-Aleutian Islands	--	366	133	183-457
Chignik	Banned	Banned	--	183-411
Kodiak	--	274	--	183-366
Cook Inlet	274	--	153 but 178 during Chinook run	165-457
Prince William Sound	274	--	--	229-274
Southeast Alaska	--	27-549	203 (<60 meshes deep) >203 (<40 meshes deep)	183-457

The commercial salmon fishery in Oregon consists only of the Columbia River gill net fishery, which is the same as that for Washington because of joint responsibility for management, and the ocean troll fishery. Drift nets are the only commercial gear allowed in the Columbia River fishery below the Bonneville Dam. Above it, set gill and dip nets are permitted in the exclusive Indian commercial fishery. Drift nets up to 457 m and set gill nets up to 91 m are legal gear. In February-March and in August, a 184-mm minimum mesh size is enforced to reduce the catch of steelhead trout. The mesh size is reduced to 114-mm mesh minimum in June-July only for sockeye throughout the Columbia River to protect the summer-run chinook salmon.

The Columbia River fishery has four seasons: winter (February-March), spring (April-May), summer (June-July), and fall (August-November) (INPFC 1979).

California, like Oregon, has banned gill net fishing for salmon and operates only an ocean troll fishery (INPFC 1979).

Other major gill net fisheries in waters of the Pacific coast states include those for herring. Exclusive gill net fishing for herring was not allowed in Alaska until 1976 where regulations adopted by the Alaska Board of Fisheries provided for 10 fishing areas in southeastern Alaska to be set aside for gill netting (Ness 1977a). Regulations for this fishery require a minimum mesh size of 5.4-cm stretch mesh. Nets can be no longer than 91 m and the maximum aggregate length allowed is 366 m per gear holder. The net is rigged with anchors and buoys and has an average fishing depth of 11 m. Although current regulations do not specify vessel type or size, the traditional boats are 5-9 m skiffs. The fishery operates only briefly (1 day) until the maximum catch quota is attained.

California also has a large coastal fishery for herring. Three gear types are involved in this fishery--purse seine, lampara, and gill net; however, the gill net is by far the most frequently used. Gill nets used in this fishery became more competitive when set or anchored nets were permitted in 1976-77. The result was that fishermen targeting primarily for herring roe shifted from round-haul nets to gill nets and this shift is continuing mainly because buyers prefer the larger fish and higher percentage of females in gill net catches.

In 1970-80, 363 vessels participated in the herring roe fishery, more than in any other commercial net fisheries in California. Of these, 306 were gill-netters.

Other gill net fisheries in California are for surface and bottom sea bass, bonito, and barracuda. Trammel nets are used for halibut and angel shark, and drift nets for thresher shark and swordfish. Average sets are about 20 to 30 pieces of net; each is 82.3 m long and 28 meshes deep. In 1975, there were 75 drift nets operating for barracuda, 56 units for sea bass, 35 units of trammel nets, and 648 units for a variety of other species.

High Seas Gill Net Fisheries

Two important high seas gill net fisheries exist in the North Pacific--one is for salmon, the other for squid.

The Japanese fishery for salmon in the North Pacific operates with mother ship fleets and land-based vessels. Mother ships are accompanied by catcher boats which fish with drift nets. Those vessels that are land-based work out of ports in northern Japan and use either drift nets or floating longlines.

The area of operation of the Japanese mother ship salmon fishery is shown in Figure 3. The number of mother ships and catcher boats that can operate in the salmon fishery is licensed by the Japanese Ministry of Agriculture and Forestry (JMAF). In 1969-78, these numbers varied from 11 to 40 mother ships and from 172 to 369 catcher boats (Table 5). Catcher boats, use monofilament gill nets with a minimum stretched mesh of 120 mm; however, more than 60% of the gill nets in use have a mesh size of 130 mm. Each catcher boat is allowed to set from 12 to 15 km of net at the maximum depending on the area being fished (INPFC 1979). Jones (1982) has estimated that annual fishing effort in the Japanese salmon mother ship fishery has

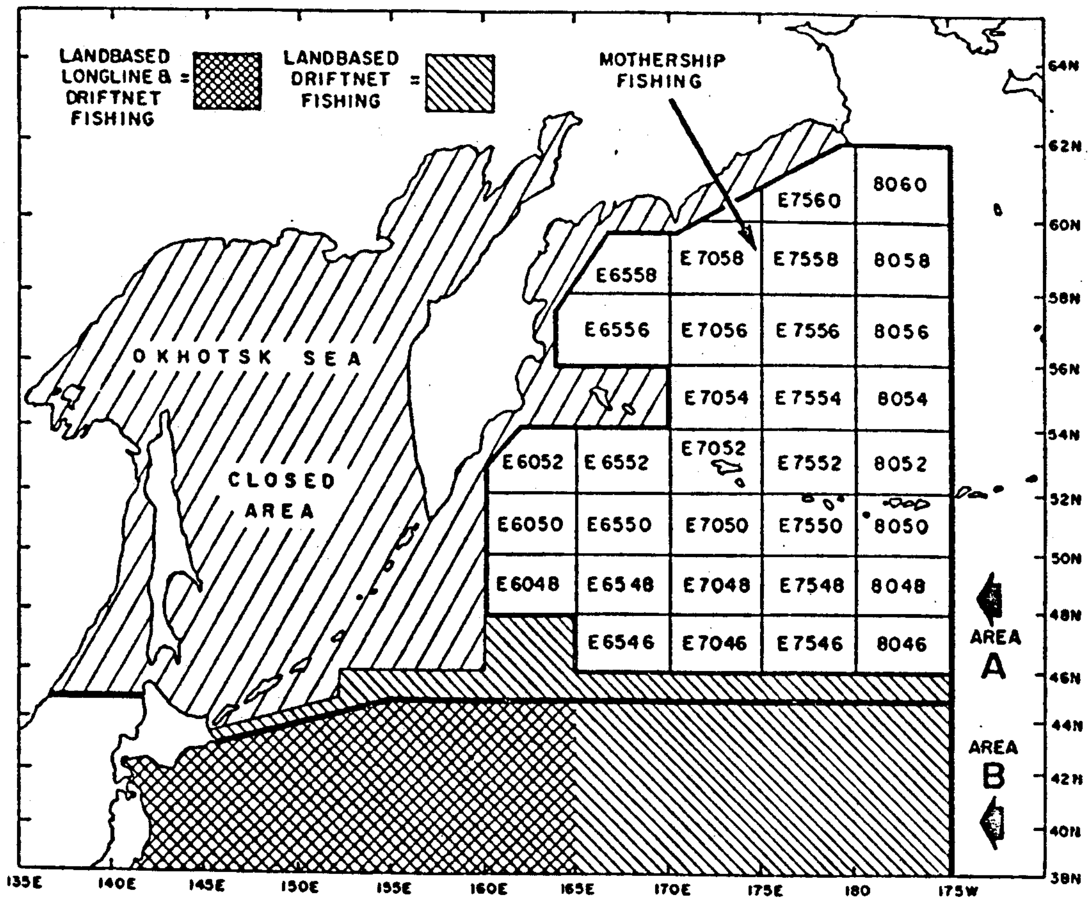

Figure 3.--Statistical areal divisions of the Japanese salmon fisheries, 1971 (International North Pacific Fisheries Commission 1971).

Table 5.--Changes in the Japanese salmon mother ship fishery during 1969-78 (effort in thousands of tans) (International North Pacific Fisheries Commission 1979).

Year	No. of mother ships	No. of catcher boats	Fishing effort[1]
1969	11	369	6,217
1970	11	369	6,028
1971	11	369	5,839
1972	10	332	5,917
1973	10	332	5,850
1974	10	332	5,433
1975	10	332	5,633
1976	10	332	5,811
1977	6	245	3,984
1978	4	172	2,721

[1]Cumulative quantity of gill net used, in thousands of tans.

fluctuated from 0.5 to 9.3 million tans (one tan is 50 m of gill net). The changes in fishing effort are related to quotas and restrictions imposed for available fishing grounds. Since 1978, effort has averaged about 3.0 million tans annually and has been concentrated in the grounds just south of the Aleutian Islands inside the United States fishery conservation zone.

In the land-based fishery, the JMAF has licensed about 325 vessels, which are required to land their catches at designated ports. These vessels use monofilament gill nets with a minimum stretched mesh of 110 mm although nets with 115 mm meshes are more commonly used. Each vessel is allowed to set a maximum of 12 or 15 km of nets (INPFC 1979). Specifications for a Japanese salmon gill net are shown in Table 6. The Japanese land-based salmon fishery operates just south of the area fished by the mother ship fleet and extends westward towards Japan. Effort in this fishery has been about 3.0 million tans annually, similar to that of the mother ship fleet.

Two fisheries that are offshoots of the high seas salmon fishery are the billfish drift net fishery (Suisan Sekai 1978) and the high seas squid fishery. Beginning full-scale operation around 1972, the billfish drift net fishery has about 395 vessels, a third of which fish with drift nets full time for billfish. The drift net used is usually 50 m long and 9 m deep. The remaining vessels in the fleet fish salmon drift nets part-time or engage in tuna longline during other times of the year.

The sudden surge of vessels entering this fishery was the result of the "oil shock" of 1973 and the Japanese Government's policy to reduce the salmon fishery fleet. Increased fuel and bait costs forced many vessels engaged in other fisheries to turn to the drift net fishery because of the advantage gained through low fuel consumption and elimination of bait costs.

The fishery now operates year round. Between July and October, billfish appear off Sanriku and after October, migrate southward, ending the Sanriku drift net fishery. Some vessels, however, continue pursuing the migrating fish and establish bases as far south as Nagasaki Prefecture in Kyushu. In addition to billfish, the drift net captures skipjack and yellowfin tunas, mahimahi, and sharks.

The fishery is not without problems. Conflicts have erupted between the drift net and skipjack tuna pole-and-line fishermen because of increased competition for the resource. Furthermore, cruising vessels have complained that occasionally they run into drift nets, resulting in propeller damage.

The Japanese squid fishery, which developed rapidly in 1978 in the northwestern Pacific, targets the red squid.[3] Most of the vessels participating are salmon drift-netters that shift to squid fishing after the close of the salmon season. This new fishery, however, like the billfish drift net fishery, met stiff opposition, mainly from the squid jigging boats. The result was that on 1 January, the JMAF restricted squid drift-netting

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[3]Court, W. G. 1979. Japan's squid fishing industry. Tokyo University of Fisheries, Tokyo, Japan, 34 p. (Mimeogr.)

Table 6.--Specifications for a Japanese salmon gill net (Food and Agriculture Organization of the United Nations 1965).

Data Sheet FAO No. 404

NAME OF GEAR:	Salmon Gillnet	Main species caught:	Salmon and trout	Vessels	Mothership based catcher boats
TYPE:	Driftnet			L. O. A.:	80 - 90 ft
COUNTRY:	Japan	Fishing conditions:	Surface; in open ocean.	Gross tonnage:	75 - 85
LOCALITY:	North Pacific Ocean			Horse power:	280 - 400
REFERENCE:	K. Mori (1961)			Crew:	20 - 22

WEBBING	A	B	C
Material	Amilon	Cremina	→
Type of knot		→	→
Preservation	O	→	→
Colour			
Twine size Tex	410	see drawing	
Breaking strength kg.	16.5		
Stretched mesh mm.	121	121	121
Upper edge	820	→	→
Lower edge	820	→	1
Depth	57	1 1/2	57
Baiting rate			
Take-up			
Selfedge			
Hanging	$\frac{a}{A} = 0.52$		

LINES, ROPES	a a_1	b b_1	c	d
Material	Manila	→	Cremina	Staple nylon
Preservation	O	→	→	→
Circumference in.	1 1/4	1 1/2		
Diameter mm.	10	12	1750 tex	
Breaking strength kg. / lb.	600 / 1325	1015 / 2250	24 / 53	30 / 66
Twist	4S and 4Z	3S and 3Z		
Lay	S	→		
Length m. / ft	51.4 / 168	50 / 164		1.21 / 4

FLOATS, SINKERS	1	2		
Number	68	62		
Material	Plastic	Lead		
Shape	Oval			
Diameter mm.				
Length mm.	200 x 60 x 38	30 x 20		
Static buoyancy Kg	0.235			
Weight in air kg.	61	75		
Weight submerged kg. lb.				

to the area north of lat. 20°N and west of long. 170°E. Japan has a squid drift net fleet of 534 vessels.[4]

Of the 110 vessels in the Taiwan squid fishing fleet, about 30 operate in the central North Pacific during May-September. The western boundary of this fishery is long. 170°W. There is no eastern or northern boundary. After the completion of the May-September season, the vessels, together with others joining the fleet, move to the western North Pacific grounds located west of long. 170°W. In the Taiwan squid fishery, the jigging and gill-netting combination vessel of about 390 GT with a length of 47 m is most popular. Driven by a 850-hp engine, these vessels carry 16-18 men and have a carrying capacity of 280 MT. The vessels are capable of remaining at sea for up to 4 months. Each of the combination vessels is typically equipped with 250 to 500 shackles of gill nets with each shackle 50 m long. The depth of the net is 6.5 m; the webbing is of monofilament vinyl chloride fibers, usually green or light blue.

Taiwan gill nets, compared with Japanese nets, are relatively cheap and are not expected to provide service for more than two seasons. The meshes of Taiwan nets are smaller than those of Japanese nets, measuring 94 mm compared with 115-120 mm. Fishing about 400 shackles of gill nets per day, the Taiwan vessels usually begin setting by 1600 to 1700 and retrieving the nets at about 0100 to 0200.

Purse Seine Fisheries

The purse seine takes fish at or near the surface. It is widely used for capturing schooling fish such as sardine, horse mackerel, tuna, mackerel, salmon, anchovy, herring, menhaden, and bonito. Purse seines usually have large numbers of floats to provide the necessary buoyancy to keep the net afloat at all times when the rings are pursed during retrieval. To prevent the fish school from escaping from the lower end, the net must be fast sinking yet have webbing as thin as practicable. Consideration must also be given to properties of the webbing, that is, it should be able to withstand tension, impact, and friction during setting and retrieving. The type of net fabricated depends on the target species; for example, night fishing for horse mackerel and mackerel does not require a fast-sinking net, but the webbing should be stiff enough to overcome deformation by currents. In daytime sardine seining, the net should be fast sinking. For tuna seining where setting is done at high speed, the net should not only be fast sinking but also be strong enough to resist the impact of tuna rushing into it to avoid capture (Nomura and Yamazaki 1975). Specifications for various kinds of purse seines used throughout the world are given in Table 7.

The purse seine can be classified as a "surrounding net" with or without bag. A lampara net is an example of the former, whereas a ring net is typical of the latter. The actual function of the seine is to form a curtain or wall of netting when a school is surrounded. The seine is buoyed at the top, weighted on the bottom, and has either a large central bunt and

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[4]Low, L.-L. 1982. Memorandum issued 13 December 1982, on "Taiwan squid fishery in the North Pacific." Natl. Mar. Fish. Serv. Northwest and Alaska, Seattle, WA 98115, 5 p.

Table 7.--Specifications for various purse seines used throughout the world (adapted from Nomura and Yamazaki 1975).

No.	Main species of fish	Country	Fishing area	Major part of net		Length of net (m) L	Depth of net	
				Stretched mesh size (cm) l	Number of yarns (210 d) y		Number of mesh in depth n	Depth (m)
1	Herring	Canada	British Columbia	3.5	15	440	2650	93
2	Herring	Iceland	Ic. Waters	3.1	9	400	3600	110
3	Herring	Iceland	Ic. Waters	3.1	9	445	2000	60
4	Herring & Mackerel	Norway	Bergen Coast	3.6	9	380	2660	96
5	Herring	Norway	Bergen Ct.	1.5	4	325	4000	60
6	Herring	U.K.	Irish Sea	4.8	9##	190	1000	48
7	Yellowfin Tuna	U.S.A.	California Waters	10.5	120##	780	750	80
8	Bluefin Tuna	Japan	Pacific Ocean	18.0	36#	1250	1500	270
9	Bluefin Tuna	Norway	Bergen Ct.	19.4	36	670	520	100
10	Horse mackerel & mackerel	Japan	East China Sea	3.75	12#	900	7500	280
11	Sardine	Japan	Pacific Ct.	4.0	12#	600	3500	140
12	Menhaden	U.S.A.	Atlantic Coast	3.75	9	600	3800	83
13	Salmon	Canada	Pacific Coast	9.0	45##	400	350	30
14	Cod	Norway	Bergen Ct.	7.0	21##	380	860	60

short wings, as in the lampara net, or has purse rings through which a pursing line passes to close off the bottom. The lampara-type net is used for horse mackerel, mackerel, anchovy, sardine, tuna, and bonito. Most present-day seines are made of nylon, vinylon, tetoron, and kyokurin (Nomura and Yamazaki 1975).

In purse seining, the fish school is first spotted and encircled with the net. After the net is set, the purse line that runs through rings on the bottom of the net is closed and the net is hauled with a power block. First to be retrieved is the lower part of the net with the rings. By hauling the net uniformly, the fish school is concentrated in the bunt, which is usually strengthened to withstand the strain. The fish school thus concentrated is then removed from the bunt in small portions with scoop nets (von Brandt 1964).

Fishing with purse seines can be classified into one-boat and two-boat operations. The advantages of a one-boat operation are that it is not labor intensive, the net can be shot in rough seas, capital investment is smaller, and operational expenses are less. Disadvantages are that the net cannot be set in shallow water, more time is needed for setting and hauling, and hauling is difficult in swift currents. In a two-boat operation, the seine can be set in shallow water, time of setting and hauling is reduced, and hauling in swift currents is relatively easy. The disadvantages are the need for larger crews, inability to operate in rough seas, and higher operational expenses (Yamaha 1984).

Net construction differs according to the species sought. In a one-boat operation to catch mackerel and large horse mackerel, nets are fabricated from webbing with No. 21 to 24 (yarn number) twine, stretched mesh size of 5-6 cm, and a buoyline varying anywhere from 495 to 975 m; the ratio of the bunt depth to the buoyline length is 0.08 to 0.15. For sardine and small horse mackerel, however, the net used has No. 18 to 24 twine and mesh size of 3.3 cm (Nomura and Yamazaki 1975), and the buoyline for a sardine purse seine used in the one-boat operation has a buoyline of 340-500 m with a ratio of bunt depth to buoyline length of 0.10 to 0.20.

In two-boat purse seining, the bunt has No. 18 to 21 twine and 5-6 cm mesh for catching mackerel and horse mackerel. Sardine seining requires a net with No. 6 twine and 1.7 cm mesh. Fishing in bays and inlets requires yet another net with No. 4 to 6 twine and 1.1 cm mesh. Tuna fishing requires a net with No. 60 to 80 twine and mesh size of 9 cm in the bunt (Nomura and Yamazaki 1975). For two-boat operations, the net is 580 to 1,000 m long at the buoyline; the ratio of the bunt depth to the buoyline length is 0.18 to 0.25. The two-boat sardine purse seine is 270-780 m at the buoyline with a ratio of bunt depth to buoyline depth being 0.20 to 0.30 (Nomura and Yamazaki 1975).

Coastal Purse Seine Fisheries

Data available on the Philippine purse seine fishery, which contributed about a third to the 1980 commercial fish production, indicate that there were 313 seiners operating in 1975; however, the number reached 413 seiners or about 17% of the commercial fishing fleet by 1980 (Encina 1982). The seines used are about 457-494 m long and 82 m deep. Fishing is done at night with lights to attract phototactic species. The most important commercial species taken include round scad, chub mackerel, yellowfin tuna, sardine, bigeye scad, herring, jack mackerel, saury, and anchovy (Bureau of Fisheries and Aquatic Resources (BFAR) 1975; Shomura et al. 1975). A fishing gear similar to the purse seine, called the ring net, is also used in the Philippines. This net combines the features of the round haul seine, which has the bunt in the center flanked by two wings, and the purse seine (Encina 1982; White and Yesaki 1982). This fishery had 158 units operating in 1980, and the principal species taken included round scad, bonito, skipjack tuna, frigate tuna, mackerel, and chub mackerel (BFAR 1975).

The surrounding net in Japan has overtaken the trawl as the single most important gear in terms of total catch. With the enactment of the 200-mile fishing zones, Japanese trawlers were forced to phase out operation in many traditional distant water fishing grounds and fish closer to their homeland, thus contributing to the relative increase in the surrounding net fishery from local waters (Yamaha 1984). In addition, technological advances in electronic fish finding equipment provided the surrounding net boats with a greater advantage, thus contributing immensely to their fishing efficiency, particularly in the sardine and anchovy fisheries.

The Japanese surrounding net fleet may be divided into three classes: large-scale boats of over 40 GT (constituting 76% of the fleet), medium-scale boats of 5-40 GT (making up 22%), and small-scale boats of <5 GT (accounting for 2%) (Yamaha 1984).

The surrounding net fishery is also divided into geographical regions in Japan. There are "northern surrounding net fisheries" which target members of the mackerel, sardine, and anchovy families in offshore waters of Hokkaido and northeastern Japan, the "west Japan surrounding net fisheries" which fish mainly for mackerel, horse mackerel, and sardine in the East China Sea, and the "pelagic surround net fisheries" for skipjack and other tunas in the western tropical Pacific.

The surrounding nets used in Japan are seines with or without pursing lines although the former type predominates. They are set by one or two boats, although recent trends have been to a one-boat operation. Sardine, horse mackerel, and mackerel make up 90% of the surrounding net fishery catch with smaller quantities of skipjack and other tunas, yellowtail, dorado, and Atka mackerel included in the remainder. In the small- and middle-scale surround net fisheries, boats in the 14.9 to 19.9 GT class are the most numerous. Net specifications for this fishery are shown in Table 8. A smaller seiner, for example, in the 8-9 GT class, will use a smaller net (Table 9).

Table 8.--Specifications: Purse seine fishing gear (Yamaha 1984).

Name	Sign	Material	No. of yarns	Mesh size	Depth	Length
Bunt	A	Nylon	210D. 18y.	23 mm	200	75 m
	B1	Nylon	210D. 12y.	23 mm	2,800	75 m
	B2	Nylon	210D. 12y.	23 mm	2,000	75 m
	B3	Nylon	210D. 12y.	23 mm	2,400	75 m
	B4	Nylon	210D. 12y.	23 mm	2,800	75 m
Body	C1	Nylon	210D. 12y.	23 mm	200	75 m
	C2	Nylon	210D. 12y.	23 mm	6,000	75 m
	C3	Nylon	210D. 12y.	23 mm	400 ~ 900	75 m
	D1	Nylon	210D. 9y.	23 mm	6,400	75 m
	D2	Nylon	210D. 9y.	23 mm	6,800	75 m
	E	Nylon	210D. 9y.	28 mm	400	75 m
	F1	Nylon	210D. 36y.	60 mm	200	75 m
	F2	Nylon	210D. 36y.	60 mm	100	75 m
Wing	C1	Nylon	210D. 12y.	23 mm	200	75 m
	D3	Nylon	210D. 9y.	23 mm	6,400	75 m
	D4	Nylon	210D. 9y.	23 mm	6,000	75 m
	F3	Nylon	210D. 36y.	60 mm	400	75 m
Selvedge	G	Nylon	210D. 60y.	34 mm	20	975 m
	H	Nylon	210D. 60y.	34 mm	20	975 m
					(No. of meshes)	

Table 9.--Net Specifications for small Japanese purse seiners (Yamaha 1984).

Fish sought	Material	Thickness	Mesh size (mm)
Horse mackerel and mackerel	Nylon	210D 9-12 y	28
Adult sardine	Nylon		16
Half-grown sardine	Nylon		12
Sardine fingerling	Nylon		9.7 or 10

In the two-boat operation where fishing is confined to daytime, the load of the net is shared by the two boats which are linked at the bow while traveling to the fishing grounds. Each seiner is equipped with its own pursing wire winch and a net hauler. Table 10 gives data on fishing grounds, boats, and nets used for various two-boat purse seine fisheries operating in the coastal waters of Japan. Detailed specifications for nets used in various one-boat and two-boat fisheries are given in Table 11.

Table 10.--Various two-boat purse seine fishing operations (Yamaha 1984).

Fishery	Sardine & horse mackeral purse seine	Luring-lamp type sardine & horse mackerel (purse seine	Gizzard shad purse seine	Hemisamph purse seine	Sardine purse seine	Sardine purse seine
Fishing ground	Kujukuri-hama Chiba Pref.	Kii channel Wakayama Pref.	Amakusa-nada Kumamoto	Shiranui-kai Kumamoto Pref.	Osaka Bay	Suruga Bay
Water depth	Under 50 m	40 ~ 80 m	40 ~ 60 m	30 ~ 40 mm	Under 50 m	200 ~ 300 m
Catch	Sardine, horse mackerel, gizzard shad, black porgy and grunt	Anchovy, horse mackerel, grunt, mackerl, mackerel scad and marusoda *(Anxis tapeinosoma)*	Gizzard shad	Hemiramph	Anchovy, sardine, mackerel, barracuda, Umazura-hagi *(Navodon modestus)* and harvest fish	Sardine, horse mackerel and mackerel
Fishing season	All year round (peak – Sept. to Dec)	All year round (peak-Apr. to Jul.)	Oct. to Apr. (peak – Oct. to Dec.)	Nov. to May (peak – Dec. to Mar.)	Jun. to Nov.	Aug. to Nov.
Fishing boat (purse-seiner)	Under 5 tons	Under 5 tons	Under 5 tons	Under 5 tons	19.7 tons	19.9 tons
No. of crew	24 ~ 30	35 ~ 40	6 ~ 8	6 ~ 8	25	32
Net size (Buoy side tailored length)	300 ~ 350 m	Approx. 600 m	100 m	70 ~ 240 m	500 m	200 m
Net material	Nylon/Cremona	Cremona	Cremona	Cremona/Nylon	Nylon	Nylon
Mesh size	28 ~ 22 mm	Body 16 mm Wing 18 mm	38 mm	Body 22 ~ 20 mm Wing 19 ~ 18 mm	11 ~ 10.8 mm	Body 11.6 ~ 11 mm Wing 9.8 mm

Table 11.--Specifications for nets used in various one-boat and two-boat fisheries (Nomura and Yamazaki 1975).

	Net				Buoy line			Lead line			Note
Kinds of purse seine	Name of parts	Kinds of materials	Number of yarns	Mesh size	Length of net	Finished length	Shortening	Length of net	Finished length	Shortening	
Two-boat type traditional purse seine	Bunt Wing	Kyokurin "	6~9 4	1.9 1.9	390m	312m	20%	390m	312m	20%	
One-boat horse mackerel	Bunt Wing	Vinylon "	18~24 12	5.4 6	1212	735	39	1363	818	40	Depth of net: 59 m Weight: 5,733 kg
– Ditto –	Bunt Wing	" "	18~24 12~18	3.0 3.0	1027	690	33				Depth of net: 272 m Weight: 8,850 kg
One-boat large sardine	Bunt Wing	" "	16 8	2.6 3.3	570	342	40	570	400	30	Center part: 8 yarns, 3.3 cm, 82 pieces
One-boat medium sardine	Bunt Wing	" "	16 6	2.0 2.2	480	288	40	480	336	30	Center: 6 yar. 2.2 cm, 100 Mesh, 82 pieces
One-boat small sardine	Bunt Wing	" "	12 4, 6	1.7 1.4	420	252	39	420	294	30	6, 1.6, 100, 30p 4, 1.5, " 20p 6, 2.0, " 24p
Two-boat horse mackerel	Bunt Wing	" "	30 24	4.3 6.0	1090	586	46				Depth of net: 106 m Weight: 4,500 kg
– Ditto –	Bunt Wing	Kyokurin Nylon	18~21 9~12	3~3.8 6.0	1162	833	28	1182	994	16	Depth of net: 83 m Weight: 8,818 kg
Two-boat sardine	Bunt Wing	" "	6 4	1.3 1.3	727	520	28	727	568	22	Depth of net: 112 m Weight: 2,430 kg
Two-boat anchovy	Bunt Wing	" "	6 6	1.6 1.6	517	273	47				Depth of net: 111 m Weight: 2,370 kg
Two-boat tuna and bonito	Bunt Wing	" Vinylon	75 24~36	9.0 15~18	2503	1730	31	2503	1818	27	Depth: 272 m Weight – Nylon; 3,094 kg, Vinylon; 5,840 kg

In the northeastern Pacific, United States and Canadian fishermen use purse seines of various dimensions in fishing for salmon and herring. The specifications and construction diagrams of salmon and herring purse seines used by Canadian fishermen are given in Tables 12 and 13. In southeastern Alaska, U.S. salmon fishermen switch to purse seining during the offseason for salmon (Ness 1977b, 1977c).

For Canadian fishermen fishing in British Columbia, the maximum legal length of salmon purse seine is 402 m in all statistical areas except in the Strait of Juan de Fuca where purse seines may be up to 549 m. Purse seines with stretched meshes <90 mm are not permitted, and in some areas seines with stretched meshes of <102 mm are not allowed on or after 20 September. Canadian seiners fishing for pink, chum, and sockeye salmon numbered 532 vessels in 1980-81 (Beacham 1984a, 1984b, 1984c).

In the U.S. Pacific coast salmon fishery, three types of purse seines are commonly used:

Puget Sound seine.--A long, deep seine of standard construction but often differing in minor details according to fishermen preference and netmaker's specifications.

Jitney seine.--A short, shallow seine of Kodiak and other Alaska areas, tailored to regulations of the Alaska Department of Fish and Game.

Alaska limits purse seines to a maximum of 457 m with shorter maximums for some areas. In southeastern Alaska, the maximum permissible length is 457 m and the minimum is 274 m. Furthermore, no net may be <25.5 m or deeper than 35.7 m. This net is as representative as any in the salmon fishery in Alaska. In other areas of Alaska, different regulations apply. For example, in Prince William Sound, the minimum length allowable is 228.6 m whereas the maximum is 274 m. The minimum depth is 17.4 m, the maximum is 31.1 m. In the Kodiak area, purse seine lengths from 183 to 377 m are allowable but at least 91.4 must be 150 meshes deep with a minimum depth of 200 meshes.

Drum seine.--The Washington State and British Columbia drum seine is short (400 m), rather shallow (300 meshes). The seine is actually rectangular with corkline and leadline nearly equal instead of having a short leadline as in regular seines.

High Seas Purse Seine Fisheries

Purse seining for tuna began as far back as 1914 when nets fabricated primarily for capturing "whitefish" (barracuda, sea bass, and yellowtail) were first used. The subsequent development of a purse seine designed specifically for tuna and the tuna fishery as it is known today is well doumented (Green et al. 1971).

The early tuna purse seines were fabricated of cotton netting but rapid deterioration of this material limited successful development of the tuna fishery. Two major technological developments--the nylon net and the power block--gave a tremendous boost to the fishery. These innovations also saved time and increased efficiency and fishing effort by allowing the

Table 12.--Specifications for a Canadian "swiftsure" salmon purse seine (Food and Agriculture Organization of the United Nations 1965).

Data Sheet

FAO No. 312

NAME OF GEAR:	"Swiftsure" Salmon Seine	Main species caught:	Mature sockeye salmon
TYPE:	Purse Seine	Fishing conditions:	Offshore, in good weather, by day, using power block.
COUNTRY:	Canada		
LOCALITY:	Pacific Coast		
REFERENCE:	P.J.G. Carrothers (1960)		

Vessels	Purse seiner
L. O. A.:	50 to 90 ft
Gross tonnage:	40 to 80
Horse power:	200 to 500
Crew:	8

WEBBING	A 6	B 2	C 1	D 7	E 1	F 1	number of strips
Material	Nylon	→	→	→	→	→	
Type of knot	Single (or double) - sheet bend						
Preservation	O or T	→	→	→	→	→	
Colour	Black	→	→	→	→	→	
Twine size Tex	1,800	1,800	1,800	1,100	2,500	1,800	
Breaking strength kg.	68	68	68	37	91	68	
Breaking strength lb.	149	149	149	82	200	149	
Stretched mesh mm.	75	75	90	90	125	90	
Stretched mesh in.	3	3	3 1/2	3 1/2	5	3 1/2	
Upper edge m	36	36	750	750	790	62	
Upper edge fm	90	90	410	410	430	34	
Lower edge							
Depth (meshes)	100	100	25	100	50	25	
Baiting rate	None						
Take-up							
Selfedge	Double twine on both sides						
Hanging	a/A = 15/20	C = 13½/A 20	a = 15/B 20	a = 285/C 410	c = 256½/E 410	e = 14/F 34	
	0.75	0.675	0.75	0.7	0.625	0.41	

LINES, ROPES	a	b	c	d	e	f	g	h	i
Material	Nylon	Polypropylene	Nylon	S.W.R	Nylon	→	Staple Nylon		Nylon
Preservation	None	→	→	Galv.	None	→	→	→	→
Circumference mm.	50	30	50	45	50	→	32	→	→
Circumference in.	2	1 1/8	2	1 3/4	2		1 1/4		
Diameter mm.	16	10	16	14	16	→	11	→	
Diameter in.	5/8	3/8	5/8	9/16	5/8		7/16		
Breaking strength kg.	5,000	1,500	5,000	9,000	5,000	→	1,000	→	
Breaking strength lb.	10,000	3,000	10,000	18,000	10,000		8,000		
Twist	Braid	→	→	Z	Braid	→	→		
Lay	H	→	→		H	→	M	→	
Length m.	550	730	495	550	25½-29	33-36½	75 x 4.50	25 x 2.10	
Length fm.	300	400	270	300	14 - 16	18-20	75 x 2½	25 x 1 1/6	

FLOATS, SINKERS	(1) Floats	(2) Sinkers	(3) Purse Rings	(4) End Rings	(5) Seine Ring
Number	2,700	8,640	75	25	4
Material	Foam vinyl	Lead	Stainless steel	Brass	Monel
Shape	Cyl.	O	split	Torus	Torus
Diameter mm.	127	35	19	12.7	19
Diameter in.	5	1 3/8	3/4 stock	1/2 stk.	3/4 stk
Length mm.	121	35	102	76	10
Length in.	4 3/4	1 3/8	4 wide	3 wide	4
Static buoyancy kg.	1.05				
Static buoyancy lb.	2.3				
Weight in air kg.	0.12	0.11			
Weight in air lb.	0.27	0.25			
Weight submerged kg.		0.1			
Weight submerged lb.		0.23			

Inshore nylon salmon seines are similar but not so deep.

Table 13.--Specifications for a Canadian winter herring purse seine (Food and Agriculture Organization of the United Nations 1965).

Data Sheet

FAO No. 301

NAME OF GEAR: Nylon Winter Herring Seine
TYPE: Purse Seine
COUNTRY: Canada
LOCALITY: Pacific Coast
REFERENCE: P.J.G. Carrothers (1960)

Main species caught: Mature Herring
Fishing conditions: Up to 100 miles from port in inshore waters (tides over two knots not fished). Spawning or feeding schools of fish are located by echo-sounders and at night are concentrated by mercury arc lights. The net is set around the school and hauled immediately, reaching to about 30 fm maximum from the surface.

Vessels Wood or steel hull
L. O. A.: 60 - 90 ft
Gross tonnage: 80 - 200
Horse power: 200 - 500
Crew: 8 - 9

WEBBING	A 1	B 4	C 6	D 1	E 11	F 1	G 1	H 1	I 1	No. of strips
Material	Nylon	→							→	
Type of knot		→							→	
Preservation	T	→							→	
Colour	Black	→							→	
Twine size Tex	1250	540	460	460	380	540	2200	1250	1250	
Breaking strength kg. lb.	54 120	23 53	20 45	20 45	17 38	23 50	91 200	54 120	54 120	
Stretched mesh mm. in.	38 1 1/2	28 1/2 1 1/8	28 1/2 1 1/8	28 1/2 1 1/8	35 1 3/8	28 1/2 1 1/8	127 5	89 3 1/2	89 3 1/2	
Upper edge	670 365	73 40	73 40	625 342	625 342	700 382	700 382	68 37	79 43	strip length in m strip length in fm
Lower edge										
Depth	25	200	200	200	200	200	25	5	5	meshes per strip
Baiting rate	None									
Take-up	Selvedge twine(s) only									
Selvedge	Double selvedge on both sides of all strips →									
Hanging	Directly to lines: 80% at bunt; 78% in body - leadline 2" shorter / 10 fm									

LINES, ROPES	a_1	a	b	c	d	e	f	g	h	i	j
Material	Polydac	→	Polypropylene	Polydac	SWR	Polydac	→	Manila	→		→
Preservation	→					→					
Circumference mm. in.	57 2 1/4	51 2	29 1 1/8	45 1 3/4	45 1 3/4	51 2	→	57 2 1/4	→	38 1 1/2	35 1 3/8
Diameter mm. in.	19 3/4	16 5/8	9 1/2 3/8	14 9/16	14 9/16	16 5/8	→	19 3/4	→	13 1/2	12 15/32
Breaking strength kg. lb.	4150 9100	3150 5900	1350 3000	2550 5600	8200 18000	3150 6900	→	2450 5400	→	1200 2650	1020 2250
Twist	Z	Z	Braid	Z	Z	Z	→	Z			→
Lay	M	M	S	M	S	M	→	S			→
Length m. fm.	110 60	440 240	585 320	530 290	640 350	51 28	44 24	57 31	50 27	4.50 2 1/2	2.30 1 1/4

	(1)	(2)	(3)	(4)	(5)	(6)
FLOATS, SINKERS	Floats	Sinkers	Purse Rings	→		Gravel Rings
Number	2700	9280	82	2	2	38
Material	Foam plastic	Lead	Monel	→	Brass	→
Shape	Cylinder	O	Torus	→		→
Diameter mm. in.	150 6	32 1 1/4	17 1/2 11/16" Ø stock	→	5/8 Ø stock	12 1/2 1/2 Ø stock
Length mm. in.	95 3 3/4	16 5/8 Ø inner	100 4	→	100 4	75 3
Static buoyancy kg. lb.	1.6 3 1/2					
Weight in air kg. lb.	0.16 0.36	0.11 0.25				
Weight submerged kg. lb.		0.10 0.23				

Floats, sinkers and purse line bridles are spaced uniformly along the seine.

seiners to set and retrieve the gear faster and to increase the number of sets possible in 1 day.

Purse seines and purse seiners have increased in size over the past two decades. During the early 1960's, a typical seine was 420 m long by seven strips deep (one strip = 100 meshes) (McNeely 1961). A net described by Coe and Vergne (1977) was 1,280 m long by 13 standard (10.8 cm mesh) strips deep. The maximum size net used in the newly developed purse seine fishery for skipjack tuna in New Zealand waters measured 1,682 m long and 263 m deep (Habib et al. 1980). The purse seines have also undergone modification by addition of a Medina panel which is a replacement webbing of 5.1 cm stretched mesh in the top strip of the net in the back-down area (Barham et al. 1977). This modification evolved as an effort by U.S. tuna fishermen to reduce mortality of porpoise which are caught in the tuna purse seine.

In the eastern Pacific tuna fishery, the number of boats in the international fleet operating each year from 1965 to 1982 ranged from 244 to 397. In 1982, of 262 tuna fishing boats participating, 220 boats or 84% were seiners (Inter-American Tropical Tuna Commission 1983). The number of tuna seiners in 1982, by size classes, is given in Table 14. Specifications of a U.S. tuna purse seine are given in Table 15.

Most Japanese tuna seiners operating in the western Pacific fishery for tuna are considerably smaller (250 to 500 GT) than the average United States seiner; however, there are a few United States type seiners in the 1,000 GT class. The purse seines used by Japanese vessels, however, are larger than those used by United States seiners in the eastern Pacific, varying from 1,025 to 2,400 m long and with depths of 110-350 m.[5] Some of the larger nets are used in two-boat seining.

Table 14.--The number of tuna seiners, by size class, fishing in the eastern tropical Pacific (Inter-American Tropical Tuna Commission 1983).

Class	Carrying capacity (short tons)	Number	Percent
1	<51	1	0.5
2	51-100	21	9.5
3	101-200	16	7.3
4	201-300	16	7.3
5	301-400	13	5.9
6	>401	153	69.5
Total		220	

[5]T. Otsu, trip to Japan report, 31 January to 22 February 1975. Available Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, P. O. Box 3830, Honolulu, HI 96812.

Table 15.--Specifications for a U.S. tuna purse seine (Food and Agriculture Organization of the United Nations 1965).

Data Sheet

FAO No. 310

NAME OF GEAR:	Tuna Purse Seine	**Main species caught:**	Tuna (yellowfin, skipjack)	**Vessels**	Purse Seiner
TYPE:	Purse Seine			**L. O. A.:**	115 to 190 ft
COUNTRY:	U.S.A.	**Fishing conditions:**	Off-shore, using power block	**Gross tonnage:**	125 to 700
LOCALITY:	California			**Horse power:**	600 to 2,000
REFERENCE:	R.L. McNeely, "Pacific Fisherman", June 1961.			**Crew:**	12 to 16

WEBBING	A_1 3 x 4	A_2 7 +3 x 3	B 3 x 4	C 4 x 1	D 3	E 4	F 2	(Number of strips)
Material	Nylon							
Type of knot								
Preservation	O							
Colour								
Twine size tex	3,100	3,100	4,200	5,000	5,000	5,000	5,000	
Breaking strength kg.	170	170	212	250	250	250	250	
Breaking strength lb.	375	375	468	555	555	555	555	
Stretched mesh mm.	105	105	105	203	106	127	127	
Stretched mesh in.	4 1/8	4 1/8	4 1/8	8	4 1/8	5	5	
Upper edge m.	165	210	36.5	210	77	210		
Upper edge fm.	90	115	25	115	42	115		
Lower edge							125	
Depth (meshes)	100	100	100	50	10	10½	15	
Baiting rate								
Take-up								
Selfedge								
Hanging	$\frac{a}{E} = \frac{90}{100}$		$\frac{e}{C} = \frac{89}{100}$					

LINES, ROPES	a	b	c	d	d_1	d_2	e	f	g	h	i	j
Material	Nylon	Poly-ethylene	Nylon	wire rope	wire rope	wire rope	chain	chain	chain	Poly-ethylene	Nylon	Nylon
Preservation												
Circumference mm. / in.												
Diameter mm.	19	16	16	16	19	16	11	6	6	13	6	5,000 Tex
Diameter in.	3/4	5/8	5/8	5/8	3/4	5/8	7/16	1/4	1/4	1/2	1/4	
Breaking strength kg. / lb.												
Twist												
Lay												
Length m.	780	10 x 77	82	600	200	292	770	124 links	240 links	1.80		
Length fm.	425	10 x 42	45		110	160	420			1		

FLOATS, SINKERS	(1) Floats	(2) Purse rings	(3) Links	(4) Rings	(5) Zipper rings	(6) End Brackets
Number	7,000	75	75	250	20	2
Material	Plastic	Galv. steel	Galv. iron			
Shape	cyl.	ring	link	ring	ring	triangle
Diameter mm.	152	19	16	13		
Diameter in.	6	5/8	3/4	1/2		
Length mm.	95	254	100	76		
Length in.	3 3/4	10	4	3		
Static buoyancy kg.	1.3					
Static buoyancy lb.	2.9					
Weight in air kg. / lb.						
Weight submerged kg. / lb.						

In the fishery for bluefin tuna off Japan, the Japanese seiner uses a net 1,250 m long, and the deepest part of the net is about 1,500 meshes deep, each mesh measuring 18 cm stretched for a total depth of about 270 m (Nomura and Yamazaki 1975).

Trawl Fisheries

The trawl fishes in midlayers down to the sea bottom or just off it for flatfish, shrimp, cod, haddock, rockfish, pollock, and other groundfish species. Basically, the trawl is a towed bag net, with a wide mouth at one end, which tapers to a narrow opening (cod end) that is tied shut during hauling. The funnellike shape of the net guides the fish towards the cod end.

The construction of a trawl net is extremely complex. It is fabricated from several panels cut according to a prescribed formula. Joining the resulting panels and ropes to form the net requires considerable knowledge of the dynamic forces imposed on parts of the net under operational conditions. Also, allowance must be made for unexpected extraordinary forces which may be exerted irregularly on the net.

The leading portion of a trawl net is called the wing, which leads backward to the body or belly (Lippa 1967). The belly then tapers off into an intermediate section and finally the cod end. The lower leading edge of the trawl mouth is hung to the footrope. The top edge of the trawl mouth is hung to the headrope as are the floats. The webbing can be either synthetic fiber or cotton. Mesh size of the webbing can vary widely from 80 to 240 mm; whereas the cod end can have meshes of 15 mm depending on the target species.

Several methods are used to keep the mouth of the trawl from collapsing during hauling. One is the use of a heavy horizontal beam. Beam trawls may be used with heavy "tickler chains," which are dragged along the sea floor in front of the net opening between the two guides on which the beam rests, to frighten fish. Being the original gear of the old steam trawlers, beam trawls are now used only on small vessels. The trawls can be towed in pairs, one on each side of the vessel; however, such operations can decrease stability unless the vessel is specifically designed for handling two trawls (Nomura and Yamazaki 1975).

Another method is to use two vessels. This method, called "bull trawling," uses a large net which can be hauled at great speeds. The most recent and widely used technique for spreading the trawl net employs large, flat boards or metal plates (otter boards) which can be rectangular or oval. The "doors," as they are commonly called, are attached to each side of the net (Nomura and Yamazaki 1975). The horizontal force provided by a pair of otter boards, which essentially act as "kites," keeps the mouth open as the net is towed through the water. Vertical forces are supplied by floats attached to the headrope and by weights attached either directly to the footrope as in the bottom trawl or on the lower spreading wires joining the footrope to the doors as in the pelagic trawl. The doors contribute significantly to the sinking forces in both types of trawl (Kerr 1972). The depth of tow can be regulated also by the amount of warp paid out and by adjusting vessel speed.

For the pelagic and semipelagic trawl, one of the basic requisites is the use of high-tenacity synthetic twines. Netting yarns, in addition to having high wet-knot breaking strength, should have particularly high extension and elasticity to equalize differences in load distribution in the fore net, thereby reducing the danger of shock loads bursting the net in heavy seas (von Brandt and Klust 1971).

The semipelagic trawl was fabricated to overcome problems in getting the mouth opening of the net to sweep the water column for fish that concentrate just off the bottom and outside the normal range of bottom trawls which have low vertical openings. Although vertical openings of these trawls can be stretched by various means, such modifications to the net usually produce a reduction in the horizontal width. New construction methods using four and six seams have produced nets of high vertical and wide horizontal openings which are considered best for bottom trawling.

There are some important differences between midwater and bottom trawling (Kutakov et al. 1971). These are:

- Because midwater trawling is aimed trawling, searches are made for schools of fish with hydroacoustic instruments. Upon detection, the vessel determines the school's depth and maneuvers into position before shooting the net and dragging through the school.

- Because midwater trawls fish in the water column between the seabed and sea surface, fish are able to dodge the oncoming net; therefore, midwater trawl nets are constructed symmetrically, that is, their top and bottom panels are equal. There is no overhang as in the bottom trawl or reverse overhang which exists in some trawls where the footrope moves ahead of the headrope.

- The mouth area and the towing speed of a midwater trawl considerably exceed those of a bottom trawl. The increased resistance of the net being hauled through the water column, however, requires increased power of the main engine.

The length of time that a trawl is towed is dictated by the catch rates prevailing. At the end of the tow, the net is hauled aboard and the cod end emptied of fish. Demersal trawls, which are designed and used primarily to scrape the sea floor, are particularly subject to damage and frequently to complete loss.

Coast Trawl Fisheries

In Japan, coastal small-scale trawls in use can be classified into four types, as follows:

- <u>Trawl without beam</u>.--Simplest of the trawls, this type consists of a net without an opening apparatus at the mouth. These trawls are either towed with one or two boats or are fastened to outstretched poles at the bow and stern of a vessel which makes use of tidal currents or wind power to get the fish into the net.

- Beam trawl.--This type of trawl has a beam of bamboo, wood, FRP, or metal to spread and hold the net mouth open.

- Dredge net.--The net has a wood or steel frame with claws made of steel or other types of metal. This dredge digs into and scrapes the sea floor as the net is towed and is used mainly for shellfish.

- Otter trawl.--The most highly developed among the trawls (Yamaha (1982b).

These various types of coastal small-scale trawls can be hauled either by side trawling or stern trawling; the latter is considered more efficient but requires a net hauler.

Except for the dredge, the other trawls are hauled either near the sea bottom or in midwater, depending on the conditions of the fishing grounds and the target species. The Japanese also engage in another type of fishing where the net is hauled near the surface layers, but this type is usually referred to as boat seining and thus is distinguished from trawling.

Concentrating on flatfish, cod, and hairtail as the major target species, the small-scale otter trawl fishery is a good representative of a coastal trawl fishery in Japan. In such small-scale trawl fisheries, the fishing gear and methods vary according to the species sought. For example, a vessel may fish with a small-mesh (20-mm stretch mesh) trawl throughout the year for various miscellaneous species but switch in winter-spring to a chain net (20-mm stretch mesh) for flatfish or in spring and autumn to a large-mesh (80-90 mm stretch mesh) net for sea bream and skipjack tuna (Yamaha 1982a).

The small-scale otter trawl has the following specifications (Table 16).

Table 16.--Specifications for a Japanese small-scale otter trawl (Yamaha 1982a).

	No of threads thickness	Mesh stretched (mm)	No. of meshes		No. of sheets
			Width	Length	
Wing net	12	28	100	100	2
Wing net	12	28	100	100	2
Wing net	12	28	100	100	2
Ceiling net	12	23	200-100	200	1
Belly net	12	28	100	300	2
Side belly net	12	28	100	300	2
Bag net	12	20	100	100	1
Fish catching section	12	20	100	200	2
Patch	12	20	100	200	2

- Towing wire rope is 8-9 mm diameter, and its length is three to four times the water depth.

- Otter boards made of wood or resin with sizes not to exceed 60 x 125 cm.

- Wing net, ceiling net, belly net, and bag net of nylon, 12 ply.

- Float of foam plastic.

- Sinker of iron or ceramic.

The boats operating in this type of fishery are usually constructed of FRP, with hull weight of 4.4 tons and a full load displacement of 9.54 tons. Overall dimensions are 14.04 m long, 32.60 m wide, and 1.63 m deep at midship.

A fishery that operates net gear in coastal shallow water and in bays is the dredge-net fishery which catches not only shellfish as was done in years past but nowadays also targets crustaceans and demersal fish. Because Japanese fishery statistics combine dredge-net catches with beam trawl catches, it is not possible to determine exactly what species are taken by this fishery; however, based on combined beam trawl-dredge net catches, the species include horse mackerel, mackerel, flatfish, cod, Atka mackerel, thornyhead, sailfin sandfish, drum, croaker, lizardfish, purple pike conger, cutlassfish, ray, sea bream, sea bass, sand lance, shrimp, crab, squid, octopus, ark shell, and sea slug (Yamaha 1983b).

Dredge nets vary widely. If the vessel is targeting demersal fish or crustaceans, the iron frame with dredge teeth is fabricated so that it slides over the sea floor on a pair of runners; special weights are added to the runner when fishing for shellfish. The total weight of the dredge net depends on the engine horsepower and towing capacity of the boat.

There is no standard shape or size or opening on these dredge nets. The usual size of the iron-frame assembly is 250-300 cm wide and 20-30 cm high, overall, when it is fitted with a fish or shrimp dredge net; however, it is 30-40 cm high when fitted with a shellfish dredge net. The dredge net is fabricated of polyethylene netting; mesh size varies according to the target species. For shellfish, the mesh is 60 mm; for demersal fish and shrimp, the meshes are 35-43 mm and 28 mm, respectively.

Along the British Columbia coastline, trawlers catch some 30 species of commercially important bottom fish including sole, cod, lingcod, rockfish, and shrimp (Lippa 1967).

Most of the Canadian trawlers are purse-seine vessels like those of the United States Pacific coast. These trawlers are stout, beamy, have a broad undercut stern, and have a wheelhouse and galley located forward (Lippa 1967). Deck space is aft and quite ample. Powered by diesels of 60-300 hp, the vessels are between 9 and 30 m long and between 5 and 100 GT, although the typical vessel is closer to 25-49 GT.

The fleet is made up of (1) year-round trawlers (fishing more than 8 months per year), (2) seasonal trawlers (4-8 months per year), and (3) part-time or incidental trawlers (<4 months per year). Vessels are classified either as single-gear trawlers, which tow from a single point (usually starboard) on the vessel, and double-gear trawlers, which tow from two points on the vessel. Many vessels use a reel on which the trawl net is wound.

There are two types of trawl nets used in the Canadian fishery; the box trawl (or western or Pacific trawl) and the flat trawl (or eastern or Atlantic trawl) (Lippa 1967). Usually, vessels up to 49 GT use the former; larger vessels use the latter. Specifications of a Canadian midwater trawl are presented in Table 17.

High Seas Trawl Fisheries

The high seas trawl fisheries in the North Pacific, perhaps the largest fishery in terms of the number of vessels involved and the number of species harvested, include fishing vessels from Japan, the U.S.S.R., Republic of Korea, Taiwan, Canada, United States, and the Polish People's Republic. The species targeted by this fleet are shown in Table 18. In the Bering Sea, pollock constituted 80% and flatfish 11% of the catch. The bulk of the catch was taken by Japanese vessels and Soviet vessels took most of the remainder. Small amounts of pollock were also taken by the Republic of Korea (Forrester et al. 1983).

Canadian and United States vessels fished mainly for Pacific halibut in the Bering Sea region and small amounts of herring were also taken by United States vessels (Forrester et al. 1983). This situation, however, changed in 1984 (D. L. Alverson, pers. commun, 26 November 1984).

In addition to groundfish, there are directed fisheries for herring conducted mainly by the Soviets, and for shrimp and small amounts of squid by the Japanese (Forrester et al. 1983).

The number of Canadian, Japanese, and United States vessels fishing in the Bering Sea region in 1954-70 and Japanese vessels fishing in the same region in 1971-76 is shown in Table 19. The number of Canadian and United States vessels operating in 1971-76 and the number of Soviet vessels operating in the Bering Sea are not available.

In the contiguous states and British Columbia, the major species taken are hake (35%), Pacific ocean perch and other rockfish (22%), flatfish (including Pacific halibut) (12%), pollock (11%), and sablefish (8%). Soviet vessels caught 47% of the groundfish, mostly Pacific hake, and Japan accounted for 26%, the United States 15%, Canada 6%, and the Republic of Korea 2%. The Polish People's Republic also caught hake in 1975-76, averaging 35,000 MT per year. The number of Canadian, Japanese, and United States vessels fishing in the northeast Pacific region in 1963-76 is given in Table 20.

Operations of the foreign trawl fisheries in the eastern Bering Sea, Aleutian Islands region, Gulf of Alaska, and off the coasts of Washington, Oregon, and California have been reported in detail by Pruter (1976), Forrester et al. (1978), Bakkala et al. (1979), French et al. (1981), Nelson et al. (1981), and Wall et al. (1981).

Table 17.--Specifications for a Canadian herring midwater trawl (Food and Agriculture Organization of the United Nations 1965).

Data Sheet — **FAO No. 123**

NAME OF GEAR:	Canadian Midwater Trawl	Main species caught:	Herring	Vessels	Canadian Fishing Boats
TYPE:	One-boat midwater Trawl			L. O. A.:	60 - 75 ft (18 - 23 m)
COUNTRY:	Canada	Fishing conditions:	Fished at depths of 15 - 35 fm (27 - 64 m)	Gross tonnage:	40 - 50
LOCALITY:	British Columbian Waters			Horse power:	150 - 175
REFERENCE:	Bulletin No. 104 by W.E. Barraclough and W.W. Johnson of the Fisheries Research Board of Canada - Biological Station - Nanaimo, B.C. (1961)			Crew:	

WEBBING	A	B	C	D	E	F	G	H	I	J
Material	Nylon	→	→	→	→	→	→	→	→	→
Type of knot		→	→	→	→	→	→	→	→	→
Preservation	Can be dyed	→	→	→	→	→	→	→	→	→
Colour	As desired		→	→	→	→	→	→	→	→
Twine size Tex	690	→	→	→	450	→	→	→	→	→
Breaking strength kg. / lb.	19.9 / 44	→	→	→	14 / 31	→	→	→	→	→
Stretched mesh mm. / in.	127 / 5	→	114 / 4 1/2	89 / 3 1/2	32 / 1 1/4	→	→	→	→	→
Upper edge	1	300	275	212	200	178	156	134	448	448
Lower edge	75	234	175	78	178	156	134	112	448	448
Depth	75	50	75	100	100	100	100	100	100	100
Baiting rate inner / outer	b / p	1 p 4 b	→	→	4p 1b	→	→	→	P	→
Take-up		$\frac{B}{C} = \frac{6}{7}$	$\frac{C}{D} = \frac{5}{6}$	$\frac{D}{E} = \frac{2}{5}$						
Selfedge										
Hanging	$\frac{a}{B} = \frac{4.90}{19.00}$ 0.26	$\frac{a_1}{A} = \frac{9.05}{9.53}$ 0.95	$\frac{b}{net} = \frac{52}{4.5}$ 1.15							

LINES, ROPES	a	a_1	b	c	d	e	f
Material	Comb.	→	Br · Nyl	→	SWR	→	→
Preservation					Gal	→	→
Circumference mm. / in.	44 / 1 3/4	→	25 / 1	→	29 / 1 1/8	→	41 / 15/8
Diameter mm. / in.	14 / 9/16	→	8 / 5/16	→	10 / 3/8	→	13 / 1/2
Breaking strength kg. / lb.	1224 / 2700	→	680 / 1500	→	3000 / 7840	→	7000 / 16,500
Construction	6 S	→	Br	→	9 x 16 S	→	6 x 19 S
Lay							
Length m. / ft	4.90 / 16	9.05 / 29 3/4	52 / 170	0.90 / 3	54.90 / 180	56.70 / 186	18.30 / 60

FLOATS, SINKERS	(1) Floats	(2) Boards	(3) Depressors	
Number	11	2	2	
Material		3/8" lam ply	1/4" steel plate	
Shape				
Diameter mm. / in.	203 / 8			
Length mm. / in.				
Static buoyancy kg. / lb.				
Weight in air kg. / lb.		61 / 135		
Weight submerged kg. / lb.				

Headline (75 1/2 ft (29 3/4' + 16 + 29 3/4')
Footrope and winglines (23 m (9.05 + 4.90 + 9.05)

Table 18.--List of scientific and common names of fish species taken in the Alaska groundfish (Forrester et al. 1978).

Scientific name	English common name (INPFC preference first)	Japanese common or standard name
Sharks		
Galeorhinus zyopterus	soupfin shark	—
Squalus acanthias	Pacific dogfish	abura tsunozame
Herrings		
Clupea harengus pallasi	Pacific herring, herring	nishin
Codfishes		
Merluccius productus	Pacific hake	heiku, merurusa
Microgadus proximus	tomcod	—
Theragra chalcogramma	Pacific pollock, walleye pollock, whiting, pollock	suketo dara
Gadus macrocephalus	Pacific cod, true cod	ma dara, tara
Rockfishes		
Scorpaenidae	rockfishes	menuke rui
Sebastes alutus	Pacific ocean perch	arasuka menuke
Sebastes brevispinis	silvergray rockfish	gin menuke, kuro menuke
Sebastes flavidus	yellowtail rockfish	kin menuke, kiobire menuke
Sebastes goodei	chilipepper	—
Sebastes miniatus	vermilion rockfish	shu menuke
Sebastes paucispinis	speckled rockfish	bara menuke, bokachio
Sebastes pinniger	canary rockfish	orenji menuke
Sebastes ruberrimus	yelloweye rockfish	kojin menuke
Greenlings		
Ophiodon elongatus	lingcod	kin mutsu
Sablefishes		
Anoplopoma fimbria	blackcod, sablefish	gin dara, hokyuo mutsu
FLATFISHES		
Hippoglossoides elassodon	flathead sole	uma garei, shiro garei
Hippoglossoides robustus	flathead sole	doro garei, shiro garei
Hippoglossus stenolepis	Pacific halibut, halibut	ohyo
Lepidopsetta bilineata	rock sole	shumusu garei, asaba garei
Limanda aspera	yellowfin sole	kogane garei, rosuke garei
Atheresthes evermanni	northern arrowtooth flounder	abura garei
Atheresthes stomias	turbot, arrowtooth flounder	abura garei
Eopsetta jordani	petrale sole	petoral nameta, tsubame garei
Microstomus pacificus	Dover sole	nameta garei, baba garei amerika nameta
Parophrys vetulus	English sole, lemon sole	igirisu garei
SHRIMPS		
Pandalus borealis	pink shrimp	hokkoku aka ebi
Pandalus goniurus	pink shrimp	benisuji ebi
Pandalus jordani	pink shrimp	—
Pandalus platyceros	prawn	—

Table 19.--Number of vessels, by type and by country, fishing for groundfish, shrimp, and herring in the Bering Sea region, 1954-76 (adapted from Forrester et al. 1978, 1983). Source: Fisheries Research Board of Canada; Fisheries Agency of Japan; Northwest and Alaska Fisheries Center, National Marine Fisheries Service, U.S. Department of Commerce; and International Pacific Halibut Commission.

	Gill net			Longline			Trawl			
Year	Canada	Japan	United States	Canada	Japan	United States	Canada	Japan[1]	Japan[2]	United States
1954	--	--	--	--	--	2	--	11	--	--
1955	--	--	--	--	--	1	--	9	--	--
1956	--	--	--	2	--	3	--	13	--	--
1957	--	--	--	--	--	1	--	13	--	--
1958	--	--	--	14	3	7	--	29	--	--
1959	--	--	--	20	6	19	--	64	--	--
1960	--	3	--	31	29	35	--	165	--	--
1961	--	[3]138	--	27	[3]138	34	--	243	54	--
1962	--	[3]67	--	33	[3]67	43	--	225	70	--
1963	--	112	--	53	115	52	--	148	93	--
1964	--	97	--	32	30	36	--	194	103	--
1965	--	68	--	15	10	19	--	149	126	--
1966	--	55	--	11	9	4	--	129	172	--
1967	--	53	--	19	7	17	--	198	173	--
1968	--	88	--	17	10	11	--	175	184	--
1969	--	64	--	16	10	7	--	186	182	--
1970	--	12	--	13	9	6	--	193	182	--
1971	--	6	--	--	13	--	--	182	182	--
1972	--	28	--	--	19	--	--	222	182	--
1973	--	14	--	--	22	--	--	154	182	--
1974	--	11	--	--	20	--	--	177	182	--
1975	--	6	--	--	23	--	--	154	182	--
1976	--	10	--	--	23	--	--	139	182	--

[1]Mother ship type groundfish fishery, North Pacific trawl fishery, and North Pacific longline-gill net fishery; includes Danish seine, pair trawl, side trawl, and stern trawl.

[2]Number of vessels licensed in the land-based trawl fishery; includes Danish seine and stern trawl. These vessels operated in the Okhotsk Sea and waters adjacent to the Kurile Islands as well as in the Bering Sea. Data are not available on the number of vessels operating in the Bering Sea region.

[3]Some vessels operated both gill nets and longlines. A detailed breakdown by gear type is not available.

Table 20.--Number of vessels, by type and by country, fishing for groundfish, shrimp, and herring in the Northeast Pacific region, 1963-76 (adapted from Forrester et al. 1978, 1983). Source: Fisheries Research Board of Canada; Fisheries Agency of Japan; International Pacific Halibut Commission; Northwest and Alaska Fisheries Center, National Marine Fisheries Service, U.S. Department of Commerce; Pacific Biological Station, B.C.

	Type of vessel													
	Gill net			Longline			Purse seine			Trawl[1]			Pots[2]
Year	Canada[3]	Japan	United States	Canada[3]	Japan	United States[4]	Canada	Japan	United States	Canada[3]	Japan	United States	United States
1963	--	3	--	236	--	342	113	--	19	77	4	268	18
1964	--	--	--	207	--	227	115	--	24	82	7	265	18
1965	--	--	--	189	--	237	132	--	28	74	13	264	22
1966	--	--	--	212	--	298	144	--	30	79	25	272	15
1967	--	--	--	151	6	286	74	--	25	81	26	312	20
1968	--	--	--	145	21	194	17	--	20	75	28	288	30
1969	4	--	--	144	26	221	19	--	43	73	33	287	9
1970	11	--	--	167	28	233	34	--	77	64	31	338	24
1971	72	--	--	154	23	111	135	--	46	64	31	314	29
1972	54	--	1	165	34	242	104	--	[5]12	56	66	[5]306	[5]39
1973	266	--	14	144	24	211	161	--	[5]27	62	31	403	[5]30
1974	1,002	--	12	76	22	165	247	--	[5]13	68	31	434	[5]39
1975	1,255	--	16	163	23	194	214	--	130	76	29	350	[5]32
1976[6]	1,068	--	105	160	22	616	188	--	173	87	25	532	85

[1]Includes Danish seine, side trawl, and stern trawl.

[2]Shrimp fishing.

[3]No data are available on the number of vessels that fished for shrimp. Data regarding the number of vessels fishing for herring were available only for the herring fishing season (approximately 1 May to 30 April of the following year); therefore, the gill net and purse seine data given here for calendar years actually are for fishing seasons, e.g., data for 1969 are for the period 4 May 1969 through 2 May 1970. No record was kept of the number of vessels that fished for herring with gill nets prior to 1969. Some vessels that trawled for groundfish also fished for herring. Vessels fishing with longlines took halibut; no data are available on number of longline, handline, or troll vessels that fished for species other than halibut.

[4]Includes about 25 vessels which fished only for species other than halibut in 1971 and 1972, an unknown number in 1973, 11 in 1974, 5 in 1975, and 415 in 1976.

[5]Number of Alaska based vessels unknown.

[6]An additional 543 United States vessels were engaged in the northeast Pacific fisheries using other gear or unclassified gear.

The Japanese fishery for groundfish in the Bering Sea developed over many years of fishing and in recent years had four principal components: the mother ship fishery, the North Pacific trawl fishery, the North Pacific longline-gill net fishery, and the land-based trawl fishery (Bakkala et al. 1979). These fisheries contributed 64, 31, 0.3, and 5%, respectively, to the Japanese catch from the Bering Sea in 1971-76.

Mother ship fishery.--This fishery consists of freezing fleets, meal and minced fish fleets, and longline-gill net fleets. Catcher boats are pair trawlers, Danish seiners, stern trawlers, and longline gill-netters; pair trawlers are the mainstay of the fleet. The number of mother ship fleets and the number of catcher boats attached to them are given in Table 21 for 1952-76. Characteristics of catcher boats and trawl gear are given in Table 22.

Table 21.--Fleet of the Japanese mother ship fishery, 1952-76 (International North Pacific Fisheries Commission 1979).[1]

Year	Number of mother ships	Number of fishing vessels[2]
1952	3	57
1953	3	105
1954	7	205
1955	14	406
1956	16	506
1957	16	461
1958	16	460
1959	16	460
1960	12	410
1961	12	410
1962	11	369
1963	11	366
1964	11	379
1965	11	369
1966	11	369
1967	11	369
1968	11	369
1969	11	369
1970	11	369
1971	11	369
1972	10	332
1973	10	332
1974	10	332
1975	10	332
1976	10	332

[1]Source: Fisheries Agency of Japan.
[2]Includes scouting boats.

Table 22.--Range in size of fishing vessels and gear in the Japanese mother ship and North Pacific trawl fisheries based on a sample of the fleets in 1976 (Bakkala et al. 1979). Source: Fisheries Agency of Japan 1976. Vessel and gear specifications of the Japanese fisheries in the North Pacific in 1976. Unpubl. manuscr., 2 p. Fisheries Agency of Japan, Kasumigaseki Chiyoda-ko, Tokyo, Japan.

		Vessels			Gear			
Fishery	Target species	Type	Gross tons	Horsepower	Headrope length (m)	Ground rope length (m)	Cod end mesh size (m)	Otter board size (m)
Mother ship	Pollock	Danish seine	96-125	450-1,450	90-130	100-143	7.5-9.0	--
		Pair trawl	115-214	650-1,400	57-130	70-160	8.0-9.0	--
		Stern trawl	299-349	1,200-1,900	48-52	57-63	8.0-8.5	1.9 x 3.2-3.0 x 4.8
	Yellowfin sole	Pair trawl	214	1,400	127	160	9.0	--
		Stern trawl	314	1,200	36	48	9.0	1.8 x 2.8
North Pacific trawl	Pollock	Stern trawl	2,455-5,470	3,500-5,700	64-80	65-111	9.0-10.0	2.4 x 3.8-3.2 x 5.0
	Yellowfin sole	Stern trawl	349-3,500	1,600-4,000	52-74	60-89	9.0-13.0	2.0 x 3.1-2.4 x 3.8
	Rockfish	Stern trawl	349-3,914	1,420-4,400	40-74	51-89	8.0-13.0	2.0 x 3.2-2.7 x 3.6

<u>North Pacific trawl fishery</u>.--This fishery consists of factory stern trawlers, which are usually larger than 500 GT and operate independently; these vessels fish and process their catch. Products, which consist of minced fish, frozen fish, and fish meal, are transferred to refrigerated transport vessels which carry them to Japan. Size of vessels and gear characteristics are given in Table 22. The main target of these trawlers is pollock in the eastern Bering Sea; Pacific cod and flounders are also caught in the trawl. In the Aleutian Islands region, target species are Pacific ocean perch and other rockfish, and smaller amounts of pollock and various groundfish constitute the remainder of the catch. There were 35-37 vessels licensed to operate in this fishery in recent years (Table 23).

<u>Land-based trawl fishery</u>.--The vessels in this fishery are essentially independent trawlers and are prohibited by Japanese regulations from transshipping their catch to cargo vessels. All vessels return to Japan after catching a full load. The target species are mainly flounder, pollock, and rattails. The gear used was mainly Danish seines; however, in recent years, the stern trawl has dominated. In 1969-76, 182 vessels operated in this fishery; however, the number declined to 143 in 1977 and to 75 in 1978 (Table 23). The catches include chiefly flounder, Pacific ocean perch, and black cod (Forrester et al. 1978).

The Soviet trawl fishery harvests a substantial part of its total catch from the Bering Sea and off the United States Pacific coast. Fishing off Alaska initially in 1959, the Soviet fleet expanded into the Gulf of Alaska and along the Aleutian Islands then moved into waters along the Alaska coastline. By 1966, they had fleets fishing off Oregon and Washington and subsequently expanded farther into waters off British Columbia and California (Pruter 1976). The Soviets are now engaged in joint venture operations (D. L. Alverson, pers. commun., 26 November 1984).

Like the Japanese, the Soviets employ the mother ships and independent factory trawlers that catch and process their own catches (Bakkala et al. 1979). This fleet concept is carried one step further in the Soviet operation, that is, the support vessels include base ships to carry administrators, staff, and to provide logistic support; factory ships to process catches; refrigerator transports to replenish stores and receive, freeze, and transport catches to port; oil tankers, passenger ships, tugs, patrol vessels, and at times hospital ships. The number of side and factory stern trawlers operating in waters off Washington, Oregon, and California in 1966-77, and off Alaska in 1963-74 is given in Tables 24 and 25, respectively. The basic types of Soviet trawlers used in the groundfish fisheries off Alaska are given in Table 26. The size of BMRT's (large freezer trawlers) and the dimensions of their trawls used to harvest walleye pollock and Atka mackerel are given in Table 27.

Trawlers of the Republic of Korea first entered the fisheries for Alaskan groundfish in 1967. Korean stern trawlers, similar in size and design to Japanese ones, target on pollock. Vessel size and fishing gear dimensions, shown in Table 28, are probably representative of the Korean trawl fleet operating in the North Pacific trawl fishery (Bakkala et al. 1979).

Table 23.--The number of fleets in the Japanese mother ship fishery and the number of vessels in the Japanese North Pacific trawl fishery, North Pacific longline-gill net fishery, and land-based trawl fishery, 1954-78 (Nelson et al. 1981). Source: Pereyra, W. T., J. E. Reeves, and R. G. Bakkala (principal investigators). 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1976. Processed rep. 619 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112; Sasaki, R. 1977. Outline of the Japanese groundfish fishery in the Bering Sea, 1976 (November 1975-October 1976). Unpubl. manuscr., 11 p., Fisheries Agency of Japan, Far Seas Fish. Res. Lab., Shimizu 424, Japan; National Marine Fisheries Service data on file at Law Enforcement Division, Alaska Regional Office, Natl. Mar. Fish. Serv., NOAA, P. O. Box 1668, Juneau, AK 99802.

	Mother ship fleets				Independent vessels		
Year	Freezing fleet	Meal and minced fleet	Longline gill net fleet	Total	North Pacific trawl fishery	North Pacific longline gill net fishery	Land-based trawl fishery
1954	2	--	--	2	2	--	--
1955	2	--	--	2	3	--	--
1956	4	--	--	4	1	--	--
1957	4	--	--	4	--	--	--
1958	2	1	1	4	--	--	--
1959	4	1	1	6	2	--	--
1960	4	5	4	13	--	--	--
1961	13	5	14	32	3	--	54
1962	11	5	5	21	2	--	70
1963	10	2	5	17	2	--	93
1964	6	4	2	12	2	--	103
1965	6	4	2	12	2	--	126
1966	8	4	1	13	2	--	172
1967	7	5	2	14	42	22	173
1968	6	5	1	12	42	22	184
1969	5	5	1	11	42	21	182
1970	3	6	1	10	42	22	182
1971	5	6	1	12	42	22	182
1972	4	6	--	10	68	33	182
1973	4	6	--	10	42	26	182
1974	4	6	--	10	42	30	182
1975	3	5	--	8	35	27	182
1976	3	5	--	8	57	32	182
1977	1	5	--	6	51	23	143
1978	1	5	--	6	54	22	75

Table 24.--Number and equivalent gross registered tonnage of different Soviet catcher vessels sighted off Washington, Oregon, and California, 1966-75. Sightings were by National Marine Fisheries Service personnel and do not include repeated sightings of the same vessels (Pruter 1976).

Year	Side trawlers				Factory stern trawlers			Equivalent gross tons, all classes
	SRT	SRTR	SRTM	Total	BMRT	RTM	Total	
1966	149	9	13	171	39	--	39	177,000
1967	--	--	--	[1]126	48	--	48	?
1968	24	--	14	38	56	--	56	194,000
1969	12	--	6	18	44	--	44	147,000
1970	--	--	8	8	55	--	55	180,000
1971	--	--	6	6	64	--	64	207,000
1972	2	--	3	5	42	2	44	141,000
1973	12	--	8	20	51	11	62	200,000
1974	--	--	--	--	78	16	94	290,000
1975	--	--	--	--	82	15	97	300,000

[1]Not differentiated by class in 1967.

Table 25.--Number and equivalent gross registered tonnage of different Soviet catcher vessels sighted off Alaska, 1963-74. Sightings were made by National Marine Fisheries Service personnel and do not include repeated sightings of the same vessels. Observations not extensive enough to provide comparative numbers in 1959-62 and unavailable for 1975 (Pruter 1976).

Year	Side trawlers					Factory stern trawlers			Equivalent gross tons, all classes
	SRT	SRTR	SRTM	SRTK	Total	BMRT	RTM	Total	
1963	155	7	--	--	162	10	1	11	79,000
1964	237	9	12	--	258	28	1	29	167,000
1965	330	11	25	--	366	36	3	39	233,000
1966	248	9	44	--	301	42	4	46	245,000
1967	191	7	66	--	264	53	4	57	279,000
1968	97	5	90	--	192	71	3	74	324,000
1969	66	9	127	--	202	79	6	85	377,000
1970	65	11	144	--	220	97	6	103	447,000
1971	92	7	102	2	203	102	5	107	438,000
1972	111	6	161	7	285	100	11	111	497,000
1973	25	7	155	9	196	105	15	120	498,000
1974	25	7	174	8	214	117	14	131	546,000

Table 26.--Basic types of fishing vessels employed by the U.S.S.R. in groundfish fisheries off Alaska (Pruter 1976).

Vessel type	Gross tons	Length (m)	No. in crew	Descriptive remarks
SRT	265-335	38	22-26	Small side trawler of older type
SRTR	505-630	52	26-28	Medium side trawler-usually transships catch to factory ship but may operate independently and process and freeze own catch.
SRTM	700	54	30	Large side trawler-frequently operates independent of factory ships and processes and freezes own catch.
SRTK	775	--	--	New class of trawler equipped with stern ramp for more efficient trawling.
BMRT	3,170	85	90	Factory trawler which normally processes and freezes own catch.
RTM	2,657	82	--	Newer type of factory trawler having increased deck area aft for more efficient handling of gear and catch.

Table 27.--Size of Soviet (BMRT) factory stern trawlers and trawl dimensions used by fishing walleye pollock and Atka mackerel as shown by data of United States observers in 1976 and 1977 (Bakkala et al. 1979).

	Range in vessel size			Typical gear dimensions			
Target species	Length (m)	Gross tons	Horsepower	Head rope length (m)	Ground rope length (m)	Cod end mesh size (cm)	Otter boards
Walleye pollack	78-87	2,657-3,837	2,000-2,320	77.4	77.4	3.0-6.0	Round to oval, variable in size 1,600-1,800 kg.
Atka mackerel	78-87	2,581-3,510	2,000	31.0	44.0	3.0-5.0	Round to oval, 1,200 kg.

Table 28.--Vessel size and fishing gear dimensions of three Republic of Korea independent stern trawlers boarded by U.S. observers in 1977 (Bakkala et al. 1979).

Vessel	Vessels data				Gear				
	Length (m)	Gross tons	Horse power	No. in crew	Headrope length (m)	Ground rope length (m)	Vertical opening (m)	Cod end mesh size (cm)	Otter board size (m)
Salvia	84	2,285	3,200	58	59	78	6	10	2.5x3.8
Shin An Ho	106	5,680	6,000	157	80	75	7	10	3.0x5.0
Heung Yang Ho	104	5,377	5,800	92	74	105	38	10	3.0x4.8

Taiwan trawlers, which first entered the groundfish fishery in 1974 and have numbered only one or two independent stern trawlers, target walleye pollock and flounder (Bakkala et al. 1979). The vessels are from 900 to 1,900 GT and can produce only frozen fish products (Nelson et al. 1981).

The size and type of trawls used by the foreign fleet in the eastern Bering Sea, Aleutian Islands region, and the Gulf of Alaska vary considerably; the specifications of the trawl net and otter boards are summarized in Tables 29 and 30.

Canadian trawlers participating in the fishery for groundfish in the North Pacific average 60 GT and range between 3 and 265 GT. In 1968-70, the fleet consisted of 65-73 vessels of which roughly 60% fish at least 6 months of the year (Table 31). The vessels are essentially the U.S. Pacific coast seiner type crewed by 2-5 men. Catches are hauled aboard the vessels by means of winches, booms, and net reels. Details of the types of net and otter boards used are given in Table 31 (Forester et al. 1978).

United States trawlers in the North Pacific groundfish fishery are essentially similar to the Canadian vessels and totaled 225 in 1970. Table 32 shows the number of trawlers operating in the fishery in 1969-70, by tonnage class and the most common types of trawl gear used (Forrester et al. 1978). The number of U.S. trawlers has increased in recent years (D. L. Alverson, pers. commun., 26 November 1984).

Miscellaneous Net Fisheries

There are a number of other miscellaneous fisheries which rely on nets although the intensity with which this gear is employed is not as great as that in the major net fisheries. Included are the set net, haul seine, and lift net fisheries.

The set net is actually a passive gear which is set in coastal waters to guide migrating fish, or those swept by currents, to follow a "lead" into one or more enclosures from which they have difficulty escaping. The haul seine, which includes the beach seine and boat seine, is set in the

Table 29.--General description of the gear used in the foreign mother ship, stern trawl, and longline fisheries during 1977-78 in the eastern Bering Sea and Aleutian Islands region. Ranges in gear dimensions were taken from U.S. observer data (Nelson et al. 1981).

Nation and vessel type	Gear type	Headrope (m)	Ground rope (m)	Cod end mesh (mm)	Otter board: Dimensions	Otter board: Shape
Japan						
Mother ship	Danish seine	120-130	130-140	90	Not applicable	Not applicable.
	Pair trawl	130-155	155-175	90	Not applicable	Not applicable.
	Otter trawl	47-54	57-65	90-100	2.2 m x 3.4 m	Rectangular
Independent stern trawl						
Large trawlers	Otter trawl	42-100	51-122	90-110	2.6 m x 4.3 m to 3.3 m x 5.8 m	Rectangular.
Small trawlers	Otter trawl	45-56	45-65	90-110	2.2 m x 3.4 m	Rectangular.
U.S.S.R.						
Independent stern trawl	Otter trawl (bottom)	30-50	44-65	100-120	5.5-6.0 m^2	Disc.
	Otter trawl (pelagic)	77	77	100-120	5.5-6.0 m^2	Disc.
Republic of Korea						
Independent stern trawl	Otter trawl	65-80	75-100	90-100	2.8 m x 4.7 m	Rectangular.

Nation and vessel type	[1]Hachi length (m)	No. of hachi/ set	No. of hooks/ hachi	Gangion length (m)	Bait
Japan longliner	70-100	390-420	35-50	1.0-1.5	Frozen squid or pollock.

[1]A hachi is a unit of length in the Japanese longline fishery used to describe a unit of gear containing a number of baited hooks which are attached to the groundline by gangions. The term "skate" is used in North American longline fisheries.

Table 30.--Summary of gear dimensions used by foreign vessels fishing in the Gulf of Alaska, 1977-78 (U.S. observer data) (Wall et al. 1981).

Nation and vessel type	Head rope (m)	Ground rope (m)	Cod end mesh size (mm)	Otter board Size	Otter board Shape	Material
Trawlers						
Japan						
Large surimi vessels	50-58.6	59-64.8	90-100	2.2x4.4 to 2.7x3.6	Rectangular	Iron or steel.
Large freezer trawlers	50-58.6	59-64.8	90-100	2.7x4.4 to 2.7x3.6	Rectangular	Iron or steel.
Small freezer trawlers	22-74.2	21-88.8	90-120	1.9x3.8 to 2.4x3.0	Rectangular	Steel or wood and steel.
U.S.S.R.						
Large freezer trawlers						
Pelagic trawl	77.4	77.4	60-120	5.5-6 m^2	Concave circular, elliptical, or rectangular	Steel.
Bottom trawl	30-50	24-48.8	60-120	5.5-6 m^2		Steel.
Republic of Korea	60-80	81-103	90-105	1.5x2.5 to 3.0x5.0	Rectangular	Steel.
Poland	121.8	121.8	100	2x4	Rectangular	Steel.

Longline vessels	Hachi (m)	No. hachi per set	No. hooks per hachi	Gangion (m)	Bait
Japan	75-100	390-420	36-58	1. 0-1.7	Squid and pollock.

Table 31.--Size distribution (gross tons) of vessels engaged in the Canadian Pacific coast trawl fishery and average type of gear used, 1968-70 (Forrester et al. 1978). Source: Fisheries Research Board of Canada.

Tonnage class	Year and number of vessels		
	1968	1969	1970
All vessels			
3-24	12	13	11
25-49	27	26	20
50-74	18	17	19
75-99	7	6	5
100-124	6	4	3
125-195	3	5	5
265	0	1	1
Total vessels	73	72	64
Average gross ton	55.1	59.3	60.9
Vessels fishing 6 months or longer in each year			
12-24	3	4	4
25-49	17	13	14
50-74	17	16	11
75-99	4	4	4
100-124	4	3	1
125-195	2	2	3
Total vessels	47	42	38
Average gross tons	59.7	61.2	60.0

Average headrope length: 21.9 m.
Average ground rope length: 28.7 m.
Mesh size in intermediate and cod end: 112 mm.
Otter board size: 2.2 x 1.2 m.
Otter board weight: 325 kg.
Otter board type: steel or wood and steel.

Table 32.--Size distribution (gross tons) of vessels engaged in the United States Pacific coast trawl fishery and average type of gear used, 1969-70 (Forrester et al. 1978).

Tonnage class	Year and number	
	1969	1970
<24	32	37
25–49	103	109
50–74	46	42
75–99	19	18
100–124	13	12
125–195	4	6
200–224	0	0
Stern ramp trawler	1	1
TOTAL	218	225
Average gross tons (excluding stern ramp trawler)	50.6	49.9
Specifications for the most common types of trawl gear used are as follows:		
	350–400 *Eastern*	350 *Groton*
HEADROPE LENGTH	58–71 ft (17.7–21.7 m)	65 ft (19.8 m)
GROUNDROPE LENGTH	81–94 ft (24.7–28.7 m)	95 ft (29.0 m)
MESH SIZE		
Intermediate and forward	3.0–5.0 in (76.2–127.0 mm)	4.5 in (114.3 mm)
Codend	3.5–5.0 in (88.9–127.0 mm)	4.5 in (114.3 mm)
OTTERBOARD		
Size	7.0×4.0 ft (2.1×1.2 m)	
Weight	760 lb (344.7 kg)	

Source: Washington State Department of Fisheries, Fish Commission of Oregon, and California Department of Fish and Game.

vicinity of known concentrations of fish, then hauled either by hand, machine power, or boats to herd the fish into the bag. In lift net fishing, the entire gear is submerged and kept there until a school of fish, lured to the net either by chumming or a light, is sufficiently concentrated. The net is then hauled quickly to entrap the fish in the bag.

Set Net Fisheries

In countries like Japan, where fish are known to migrate along the coast, conditions are very favorable for set net or fixed net fisheries. In areas where set net fisheries have developed, coastal currents are usually moderate, the coastline is uneven and interrupted by numerous bays, and weather conditions are ideal (Nomura and Yamazaki 1975). Exceptions are in places like Hokkaido where winter conditions can severely limit fishing.

Of the three types of set nets formerly used in Japan, the "otoshi ami" is the only one remaining and can be found in major bays along the Japanese coast including Sagami Bay, Kamano Bay, Tosa Bay, Toyama Bay, and Wakasa Bay.

The Japanese classify set nets as large, medium, and small. Examples of large set nets can be found in Mie Prefecture where they are fixed in water depths of about 30 m over mud and mud-sand bottom to catch yellowtail, tuna, sardine, mackerel, horse mackerel, and other coastal species.

The Japanese coastal fishery for salmon, which operates mostly in the Sea of Japan and along the eastern and western coasts of the northern half of Japan, also relies heavily on set nets in the nearshore areas. Most vessels make short 1-day trips in territorial waters. A few, however, make 2-3 day trips. In 1967-79, the set net produced about 26% of the total Japanese salmon catch.

The "otoshi ami" used in the salmon fishery consists of a leader net and a main net which has three components--the playground net, the funnel, and the trap net, which can be attached on either one or both sides.

Although the upper margins of the nets are fixed to be at sea surface, there has been a trend in recent years to set the net in deep waters of 50-60 m with the upper margins reaching only to the midlayers in the water column. This move toward deepwater sets was prompted by severe winter conditions, particularly around Hokkaido where bad weather severely restricts fishing (Yamaha 1980). These deepwater sets have produced higher catch rates than surface sets.

Among set nets of medium size is the sardine trap net. This net has an ascending portion, a trapping portion, and a fence net. Set 1.8-3.7 km from shore, the net measures 120 m long by 80 m wide and varies in depth from 20 to 40 m. The pocket is 18 m long and 50 m wide. Operation of the net requires three boats--one to raise the bag net entrance and the others to lift the entire remainder of the net. Fished mainly in spring and summer, these nets capture sardine as well as mackerel, horse mackerel, squid, and other species. These nets are fished along the Pacific and Sea of Japan coasts of Honshu.

Another set net of medium size is the herring trap net, used mainly along the coast of Hokkaido. This net usually measures 45 m long and 20 m wide in the bag net and has a 150 m long leader net. Operated by three boats, the net is usually fished for only 3 months from March through May. One boat lifts the net while the others serve as carriers. The target species is spawning herring.

A small trap net is operated year round in many small bays along the Japan coast. Consisting of a main net, leader net, and bag net with flappers, the net is operated by one boat crewed by two to three fishermen. Species taken usually include sea bream, Spanish mackerel, perch, cuttlefish, flatfish, croaker, and squid.

Haul Seine Fisheries

The haul seine is operated on the same principle as the trawl; that is, the net is dragged along the sea floor or in midwater. Essentially, the net has long wings which serve as barriers that drive the fish toward the bag. The top line or upper edge of the net is buoyed with floats whereas the bottom line, which drags along the sea floor, is weighted with sinkers. Most nets have pocket bunts similar to the cod end of a trawl. This pocket usually is made of heavy webbing to hold the fish. It can be centered, in which case the net is symmetrical, or off to one side or asymmetrical (Torban 1964).

Haul seines vary from small 100 m nets to large 2,000 m ones (Kask 1947; Torban 1964). Depth varies from 10 to as much as 40 m in some European nets. The cod end or pocket can be 10-12 m long. Meshes in the wing are graduated from 75 to 15 cm; the meshes near the center are smaller (1.5 to 2.0 cm). The ground lines and float lines are 1.5 cm in diameter; whereas the hauling lines or warps, attached to the wings, are 2.0 cm in diameter and about 1,500 m long. The warps serve a dual purpose; in addition to their use as a hauling line, some fisheries use the warps as frightening devices by attaching twigs, leaves, or straws to them.

Haul seines such as beach seines can be used in shallow water where fish are known to aggregate. The net is usually set with the aid of a skiff at the direction of a fishing master. Hauling in the warp and net can be done by hand but this operation requires considerable labor. Some European beach seine fisheries now resort to mechanical haulers.

The Hawaiian "hukilau" net is a typical example of a beach seine which requires many helping hands in hauling. The leaves of the ti plant are attached to the warp of this net which serves as a scare line. Species most commonly caught in the hukilau nets are jack, threadfin, bonefish, milkfish, goatfish, and mullet.

Okinawan fishermen use a variation of the haul seine which is set from two boats but also requires many hands. In this method, the haul seine is set at designated fishing grounds by small fishing boats, then the fishermen enter the water and begin hitting the surface with their hands or scare lines to startle the fish and drive them out from their hiding places between rocks and within coral heads. Some of the fish, in attempting to escape, become entangled in the wing net; however, most are driven toward the bag which is then hauled aboard the boats. Species caught by this method usually include wrasses, parrotfishes, golden banded fusiliers, and flyingfishes (Yamaha 1979b). Similar fishing methods are used in the Philippines where the fishery ranks fifth in terms of commercial fish production (Encina 1982). The major species caught are <u>Caesio</u> spp., parrotfish, snapper, siganids, and nemipterids.

The Japanese have a form of net fishing called boat seining in which fish are caught by filtering midlayer waters with a net. The gear used in this type of fishing is different from that used in bottom trawling operations, and the target species differ (Yamaha 1983a).

Boat seining requires the following:

- <u>Wing net</u>.--Section of the net used to intimidate the fish and promote school formation.

- <u>Main net</u>.--This section prevents fish from escaping while guiding them into the bag area.

- Bag net.--This section holds the fish.

- Tow rope.--Rope used by the boat to tow or hold the net.

One type of boat seine ("patchi ami") in Japan is the largest net used in any of the boat seine fisheries, requiring two boats of up to 20 gross tons to tow it (Yamaha 1983a). Based on 1983 data, there are about 700 groups operating out of central and southern regions of Japan's Pacific coast. Target species for this fishery are sardine, anchovy (adults and fry), sand lance, and cuttlefish; however, sardine and anchovy predominate in the catch.

In "patchi ami" seining, the two boats are tied together at the bow and share the load of the net as they head toward the fishing grounds. After a school is located by a fish-finder on a search boat, the two boats are positioned up current from the school then advancing with their bows still joined, they lay out the buoys and then the bag net into the water. At this point, the two vessels separate and head off in opposite directions at full speed, laying out the main net and wing net as they steam along. When the entire net is set, the two boats turn 90° and run parallel to each other in the direction of the school, laying out sufficient tow rope to bring the mouth of the net to about the same depth as the fish school. When the net is finally positioned at the proper depth, towing begins.

In retrieving the net, the two boats come together and are again secured at the bow. Net haulers commence the retrieval onto large drums or reels mounted on the deck; however, the main net is hauled in by hand. Then the bag net is brought up to the surface, a transport boat is called up to the stern of the two net boats, and picks up the buoy, buoy line, and the bag net. Net specifications for this fishery are given in Tables 33 and 34.

Another type of boat seining called "gochi ami" (type B) in Japan, can be either a one- or two-boat operation. The net, which has a high ratio of shrinkage in the center section, expands into a large bag when placed across a current or towed (Yamaha 1983a). This net is ideal for towing alongside reefs or near the sea bottom; thus it can be used in places such as rough or rocky bottom where a standard bottom trawl cannot be used. It is highly effective in fishing for red sea bream, threeline grunt, silver whiting, lizardfish, barracuda, and porgy.

One-boat operations usually harvest small fish, whereas two-boat groups target large fish. The specifications of the net in a one-boat operation are presented in Table 35.

Lift Net Fisheries

Three typical examples of lift nets are the basnig (bag net) used in the Philippines, the conical type such as that used in the Hawaiian opelu (*Decapterus* spp.) fishery, and the stick held net used in Japan.

The main characteristic of this fishing method is that the net remains submerged until ready to be hauled up vertically and at least partially out of the water to catch fish, which congregate above it (Ben-Yami 1976).

Table 33.--Specifications for a Type A boat seine ("patchi ami") (Yamaha 1983a).

Name of parts	Mark	Material	Thickness	Mesh size	Quantity
Wing net	a	Polyvinyl alcohol	11 mm	240 cm	2
Main net	b	Polyvinyl alcohol	8 mm	120 cm	2
	c		7 mm	60 cm	2
	d		6 mm	30 cm	2
Mouth of bag net	e	Polyvinyl alcohol	6 mm	24 cm	2
Bag net	f	Nylon	No. 4 (0.329 mm) x 4 yarns	0.5 mm (Japanese minnow net-105 yarns per 50 cm)	2
	g				2
	h				2
	i				2
	j				2
	k				2
Trap (inside of bag net)	l	Nylon	*	0.5 mm	2
Sale rope	m	Polyvinyl alcohol	18 mm (diameter)	--	2
	n				2
Head rope	o	Polyvinyl alcohol	18 mm (diameter)	--	2
	p				2

Table 34.--Differences in specifications of Type A boat seine ("patchi ami"), by area, type of operation, and species targeted (Yamaha 1983a).

Area	Type	Main catch	Head rope length (m)	Bag net height (m)
Fukuoka, Nishiura	Two-boat operation	Red sea bream, etc.	45	20.2
Fukuoka, Fukuyoshi	Two-boat operation	Grunt and red sea bream	38.4-40.5	30
Saga, Tobo	Two-boat operation	Grunt and red sea bream	38.4-40.5	45
Saga, Tobo	One-boat operation	Sillaginoid and barracuda	27	18
Nagasaki, Aou	--	Red sea bream and grunt	22.5	15
		Red sea bream lizardfish and barracuda	22.5	15
		Lizardfish and barracuda	18	6-6.5

Table 35.--Specifications for a type B boat seine ("gochi ami") (Yamaha 1983a).

Mark	Name	Material	Standard No. of yarns	Standard Mesh size (mm)	No. of meshes Width	No. of meshes length	No. of sheets
A	Wing net	Nylon	36	61	4	4.5	2
B	Wing net	Nylon	6	43	100	5.7	2
C	Wing net	Nylon	6	43	50	7.2	2
D	Wing net	Nylon	6	43	100	7.2	2
E	Upper salvage	Polyvinyl alcohol	30	43	5-10	600	1
F	Bottom salvage	Polyvinyl alcohol	40	50	5-10	600	1
G	The side of bag net	Nylon	6	43	100	800	2
H	The bottom of bag net	Polyvinyl alcohol	8	38	150	250	1
I	Shirk net	Nylon	12	43	50	7.2	2
J	Upper triangle	Polyvinyl alcohol	30	43	25	25	2
	Lower triangle	Polyvinyl alcohol	40	50	20	20	2

Most lift net fishing is done with attracting lights, although the Hawaiian opelu net is used in conjunction with chumming.

The lift net is best for catching fish that form dense and compact aggregations. In the Philippines, the basnig is operated with a night light during the dark phase of the moon (Encina 1982). The gear consists of a pair of bamboo rafts, dugout, poles or booms, and a large net somewhat like an inverted mosquito net.

Improvements in the gear after World War II included larger boats propelled by marine diesel engines. To increase lighting power and thus attract more fish, high candlepower lamps or generators were used (Encina 1982).

In 1980, the basnig fishery contributed 106,194 MT of fish or roughly 21.7% of the total commercial fish production. The fleet consisted of 624 units or 26% of the total commercial vessels operating. Species targeted by the basnig fishery include round scad, anchovy, sardine, and slipmouth (BFAR 1975; Encina 1982). Table 36 gives the specifications and configurations of the net.

The Japanese stick-held lift net is used principally in the saury and mackerel fisheries in which the vessels have a large battery of lights. These lights can be classified into fish searching lights, fish gathering lights, and fish leading lights. The first step involves the use of searchlights to search for fish schools. The net, which is suspended from outrigger bamboo poles or booms and hauled toward the vessel when retrieving, is set after a school is located and the fish gathering lamps are turned on to attract the fish to the boat. A red, fish leading lamp with adjustable light intensity concentrates the school over the net (Nomura and Yamazaki 1975). This method of fishing has an advantage in that the net cannot only be adjusted to a specific light attraction system, but also

Table 36.--Specifications for a Philippine basnig (Food and Agriculture Organization of the United Nations 1965).

Data Sheet **FAO No. 501**

NAME OF GEAR:	Basnig (Bagnet)	Main species caught:	Sardines, Mackerel, Round Scad	Vessels	Launch
TYPE:	One-boat lift net			L. O. A.:	26 m (85 ft)
COUNTRY:	Philippines	Fishing conditions:	Depth: 10 - 30 fm Sandy, muddy bottom. Calm to strong breeze, current 1 - 2 knots Duration of operation: 1/2 to 1 1/2 hours. Fish attracted by electric lights above surface.	Gross tonnage:	75
LOCALITY:	Visayan Sea and Vicinity			Horse power:	310
REFERENCE:	Philippine Journal of Fisheries, Vol. 3, No. 1 pp 318 - 320			Crew:	25

See also Modern Fishing Gear of the World

WEBBING	A	B	C	D ø	E ø	F ø	G ø
Material	Cotton	→	→	→	→	→	→
Type of knot		→	→	→	→	→	→
Preservation	C	→	→	→	→	→	→
Colour							
Twine size Tex	300	→	→	300	→	→	→
Breaking strength kg. lb.							
Stretched mesh mm.	20	→	→	40	→	→	→
Upper edge	1500	2500	1500	750	6	6	750
Lower edge	1500	2500	1500	750	6	6	750
Depth	500	2000	500	6	1000	1000	6
Baiting rate	all p	all p	all p	all p	all m	all m	all p
Take-up				D:A=1:2	E:B=1:2	F:B=1:2	G:C=1:2
Selfedge							
Hanging m	0.5 15/30	0.5 20/40	0.5 20/40	0.5 15/30			

LINES, ROPES	a	b	c	d	a_1	b_1	c_1	d_1	e
Material	Cotton	→	→	→	→	→	→	→	Abaca
Preservation	C	→	→	→	→	→	→	→	O
Circumference in.	1 1/4	→	→	→	5/8	→	→	→	2 1/4
Diameter mm.	11	→	→	→	5	→	→	→	18
Breaking strength kg. lb.									
Construction	S	→	→	→	→	→	→	→	→
Lay	M	→	→	→	→	→	→	→	→
Length m.	15	20	20	15	15.6	20.8	20.8	15.6	55

FLOATS, SINKERS	(1)			
Number	12			
Material	Lead			
Shape				
Diameter mm. in.	89 3 1/2			
Length mm. in.	102 4			
Static buoyancy kg.	6 - 8			
Weight in air kg. lb.				
Weight submerged kg. lb.				

Accessories:

Electric generator	1 x 25 kva
Electric lamps	20 x 1 Kw

can be used to corral the fish between the net and the vessel's hull, thus reducing the chances of escape (Ben-Yami 1976).

ESTIMATES OF THE AMOUNT OF NET GEAR AVAILABLE FOR USE

The preceding sections demonstrated the diverse nature of net gear in use in the North Pacific, even within the same fisheries. Gill nets, trawls, and purse seine vary greatly in construction and design that it is almost impossible to designate one type as being typical for a particular fishery. For example, gill nets vary widely in length, mesh size, hanging ratio, thread size, and color so that there is no "typical" gill net for any one species. Likewise, trawls and purse seines vary considerably in size, webbing, meshes, and configuration. This variation in gear results from many factors, among them being fishermen or net manufacturer's preference, the behavior and life stages of the species sought, and regulations adopted for the fisheries.

Although there is wide variation in gear, what is of interest is a perspective of how much net gear is actually available to any given fishery. This estimate should provide an idea on the extent to which derelict fishing gear can become a component of the marine debris in the North Pacific. The estimates of available gear in the major net fisheries are first-order approximations based on data presently available.

Estimates of the amount of net gear available for use in the North Pacific are given in Table 37. It should be pointed out that because the data contained in Table 37 represent mostly major or large fisheries, the estimates are minimums. Many small, coastal fisheries have not been considered in the computation.

It can be seen in Table 37 that the amount of gill net used in the North Pacific far outstrips that of purse seines, trawls, and miscellaneous gear such as boat seines, set nets, and lift nets. Nearly 3.5 million units (shackles, Japanese tan, etc.) of gill net are available to the major fisheries. Strung end to end, these nets would stretch over 170,000 km, a distance 4.2 times the length of the Earth's Equator.

SPECULATION ON GEAR LOSSES

Because gear losses are never reported, it is not possible to estimate the extent to which they occur in any fishery. There is no doubt, however, that within the past two decades, fishing pressure on all the fishery stocks in the world's oceans has increased dramatically, and with it there has been a concomitant increase in the amount of fishing-related debris dumped into the sea (Wehle and Coleman 1983). Furthermore, the kinds of debris and derelict fishing gear finding their way into the ocean has changed. Whereas fishing nets manufactured before the "synthetic boom" were made of natural fibers and, therefore, were degradable within a relatively short period when they became derelict, the synthetic nets, ropes, and lines of the past three decades, when lost, were more buoyant, longer lived, and in some cases nearly invisible under water. The result of this change in fibers used for netting and lines has meant an increase in mortality of not only marine animals but also marine organisms. Unlike

Table 37.--Estimates of total length of nets available to the major net fisheries of the North Pacific (BFAR = Bureau of Fisheries and Aquatic Resources; PRC = Peoples Republic of China; IATTC = Inter-American Tropical Tuna Commission; INPFC = International North Pacific Fisheries Commission; JMAF = Japan Ministry of Agriculture and Forestry).

Fisheries	Net length: Float line (m)	Net length: Head-rope (m)	Net length: Foot-rope (m)	Total units per available boat (No.)	Boats (No.)	Total fishing units (No.)	Estimated total length of net available for fishing (km)	Source of data
Gill Net Gear								
PRC coastal Spanish mackerel	[1]26	--	--	--	--	426,000	11,076	Zhu 1980.
Taiwan high seas squid	50	--	--	500	63	31,500	1,575	Footnote 2 in text.
Japanese coastal salmon	[1]50	--	--	40	1,380	55,200	2,760	INPFC 1979; Nomura and Yamazaki 1975.
Japanese coastal billfish	50	--	--	[1]300	395	118,500	5,925	Suisan Sekai 1978.
Japanese coastal sardine, herring, and others	[1]50	--	--	[1]40	60,919	2,436,760	121,838	JMAF 1981.
Japanese high seas salmon	50	--	--	300	172	51,600	2,580	INPFC 1980.
Japanese land-based salmon	51.4	--	--	290	325	94,250	4,844	INPFC 1979
Japanese Bering Sea groundfish	46	--	--	[1]300	10	3,000	138	Forrester et al. 1983.
Japanese high seas squid	[1]50	--	--	[1]400	534	213,600	10,680	Footnote 2 in text.
Canadian salmon	366	--	--	1	2,508	2,508	917	Beacham 1984a, 1984b; Argue et al. 1983.
Canadian northeast Pacific herring	366	--	--	12	1,068	12,816	4,550	Forrester et al. 1983; Hourston and Haegele 1980.
U.S. coastal set net salmon	192	--	--	--	--	3,045	585	U.S. Department of Commerce 1978.
U.S. coastal miscellaneous species (California)	82	--	--	30	509	15,270	1,252	Spratt 1981; Pleschner 1983.
U.S. coastal drift net salmon	274	--	--	--	--	5,113	1,401	U.S. Department of Commerce 1978.
U.S. northeast Pacific groundfish	[1]274	--	--	12	105	1,260	345	Forrester et al. 1983.
Total						3,470,422	170,466	

Table 37.--Continued.

Fisheries	Net length: Float line (m)	Net length: Head-rope (m)	Net length: Foot-rope (m)	Total units per available boat (No.)	Boats (No.)	Total fishing units (No.)	Estimated total length of net available for fishing (km)	Source of data
				Purse Seine Gear				
PRC coastal	600	--	--	1	[2]165	165	99	Solecki 1966.
Philippines coastal	494	--	--	1	[2]471	471	233	(Philippines) BFAR 1975; Shomura et al. 1975.
Japanese one-boat coastal	731	--	--	1	[2]650	650	475	JMAF 1981.
Japanese two-boat coastal	1,100	--	--	1	[2]168	84	92	JMAF 1981.
Japanese tuna	2,400	--	--	1	[2]73	73	175	JMAF 1981.
Canadian salmon	402	--	--	1	532	532	214	Beacham 1984a, 1984b.
Canadian northeast Pacific herring	[1]440	--	--	1	188	188	83	Forrester et al. 1978, 1983.
U.S. coastal salmon	457	--	--	1	[2]1,231	1,231	563	U.S. Department of Commerce 1978.
U.S. northeast Pacific herring	457	--	--	1	173	173	79	Forrester et al. 1978, 1983.
Eastern Pacific tuna	1,200	--	--	1	220	220	264	IATTC 1983.
Total					3,316	2,044		
				Trawl Net Gear				
South China Sea otter	--	40	54	1	[2]10,667	10,667	[3]1,003	Aoyama 1973.
South China Sea pair	--	100	[4]135	1	[2]8,090	4,045	[3]950	Aoyama 1973.
Japanese coastal small	--	55	65	1	[2]28,372	28,372	[3]3,405	JMAF 1981.
Japanese mother ship Danish seine	--	130	140	1				
Japanese mother ship pair	--	155	175	1	332	166	[3,5]55	INPFC 1979; Bakkala et al. 1979.
Japanese stern	--	52	63	1				
Japanese land-based	--	[1]54	[1]65	1	75	182	[3]22	Nelson et al. 1981.
Japanese independent	--	52	63	1	54	54	[3]6	Nelson et al. 1981.

Table 37.--Continued.

Fisheries	Net length: Float line (m)	Net length: Head-rope (m)	Net length: Foot-rope (m)	Total units per available boat (No.)	Boats (No.)	Total fishing units (No.)	Estimated total length of net available for fishing (km)	Source of data
Canadian northeast Pacific herring	--	22	29	1	87	87	[3]4	Forrester et al. 1978, 1983.
U.S. northeast Pacific groundfish	--	20	29	1	532	532	[3]26	Forrester et al. 1978, 1983.
Soviet Bering Sea groundfish	--	77	77	1	345	345	[3]53	Pruter 1976.
Soviet northeast Pacific groundfish	--	77	77	1	97	97	[3]15	Pruter 1976.
Total						44,547	[3]5,539	
Miscellaneous Net Gear								
Japanese two-boat seining ("patchi ami")	--	[1]45+ [6]436	[1]45	1	[2]1,430	715	376	JMAF 1981.
Japanese one or two-boat seining ("gochi ami")	--	27	[1]27	1	7,082	7,082	382	JMAF 1981.
Japanese stick held lift net	200	--	--	1	5,232	5,232	1,046	JMAF 1981.
Philippine basnig	70	--	--	1	624	624	44	Encina 1982.
Japanese set net	[7]400	--	--	1	17,565	17,565	7,026	Kask 1947; JMAF 1981.
Total						31,218	8,874	

[1]Estimated from information on related fisheries.
[2]Assumption based on number of units operated.
[3]Calculation based on headrope and footrope lengths.
[4]Based on proportions of otter trawl.
[5]Based on data for pair trawlers, which predominate in fisheries.
[6]Total length of right and left wing nets.
[7]Total length of leader net and main body.

working nets, which are set and retrieved within a specific time period, the free-floating derelict net, often broken into large and small fragments, fishes indefinitely, thus representing miles of entanglement for fish, crustaceans, molluscs, marine mammals, turtles, and seabirds.

Of the various net gears reviewed, the gill net is perhaps the most likely to become lost or damaged and discarded during fishing operations. In the Icelandic cod fishery, for example, each gill-netter fishes about 100 nets per day. These nets last only a few weeks and each boat can use up to 400 nets in a 4-month season (Frechet 1964). Although bad weather is probably responsible for some of the nets lost or damaged, heavy fishing and shark damage also account for a good proportion of the nets being lost or discarded.

One study conducted by High (1981) demonstrated that derelict gill nets have the potential for causing major fish losses. Visits to sites where sunken derelict gill nets were found showed that they remained intact and continued to capture fish for more than 2 years. Living and dead fish of several species and numerous crabs were always present in one of the nets that covered about 186 m^2 (2,000 ft^2).

The ubiquitous gill net is without doubt the gear most disliked by the nongill net segment of the fishing industry, yet it provides support for many fishermen throughout the world. And although it is true that "gearing up" with gill nets to participate in a fishery does not require the kind of capital investment needed to enter a purse seine or trawl fishery, gill-netters, nevertheless, do encounter high losses in gear as well as in catches. For example, marine mammals have been accused of "gnawing a sizable gash" in the catches of commercial fishermen (Pleschner 1983). It has been estimated that seals alone cause losses totaling at least US$10,000 per boat per year.

In the purse seine and boat seine fishery, one can hardly expect gear losses to be high, because the operation requires that at least one end of the net be secured to the vessel at all times; however, it is possible for nets to become entangled on rocky bottom or coral if sets are made in shallow water. Net damage is also likely to occur if large predators, for example, sharks are caught together with small target species.

Trawls, like gill nets, can be easily lost should they become "hung up" on the bottom during trawling operations. Also, bottom trawls are highly susceptible to damage when being hauled over rough bottom. Loss and damage to trawl gear are probably highest during and immediately after the exploratory fishing phase when grounds are still unfamiliar to the trawl fishermen.

Among the miscellaneous gear, the lift net is unlikely to be lost since almost all operations are conducted over still, quiet waters. Moreover, the nets are attached to lines which are run to outriggers or bamboo poles that are secured to the fishing vessels. Fishing operations can be halted at any time and the net removed from the water should it become necessary to do so during sudden storms and changes in sea conditions.

The set net, on the other hand, can be subjected to severe damage or lost entirely, because for much of the time that the net is in the water, it is unattended. Although most set nets are strategically placed in locations where weather and sea conditions are not expected to be adverse, sudden storms and the resulting heavy seas could generate currents strong enough to break the mooring or anchor lines attached to the set nets, thereby setting them adrift to become components of marine debris.

SUMMARY

The major net fisheries of the North Pacific are reviewed to develop some perspective of the amount of gear available to them for fishing. For the 15 major gill net fisheries in the North Pacific, it was estimated that roughly 170,000 km of netting were available to them for fishing. For the 10 purse seine fisheries, the netting available was estimated to be a little over 2,000 km, whereas for 12 trawl fisheries the estimate reached 5,500 km.

Among the various net gear discussed, it was speculated that gear losses were highest in the gill net fisheries, followed by the trawl fisheries and set net fisheries. Because modern net gear is fabricated predominantly with synthetic webbing, and therefore, nondegradable, derelict netting remains a part of the marine debris indefinitely thus threatening air-breathing animals as well as fish, crustaceans, and molluscs in the marine environment.

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Appendix Table 1.--English and scientific names of fishes, molluscs, and crustaceans mentioned in this report.

English name	Scientific name
Abalone	Haliotidae
Albacore	*Thunnus alalunga*
Anchovy	Engraulidae
Angel shark	Squatinidae
Ark shell	Arcidae
Atka mackerel	*Pleurogrammas monopterygius*
Barracuda	*Sphyraena* sp.
Bastard halibut	*Paralichthys olivaceus*
Bigeye	*Priacanthus macracanthus*
Bigege scad	*Selar crumenophthalmus*
Billfish	Istiophoridae
Black porgy	*Acanthopagrus latus*, *A. cuvieri*
Bluefin tuna (northern)	*Thunnus thynnus*
Bonefish	*Albula vulpes*
Bonito	*Sarda* sp.
Bream	Sparidae
Chinese herring	*Ilisha elongata*
Chinook salmon	*Oncorhynchus tshawytscha*
Chub mackerel	*Rastrelliger* spp.
Chum salmon	*Oncorhynchus keta*
Clam	Pelecypoda
Cod	Gadidae
Coho salmon	*Oncorhynchus kisutch*
Crab	Brachyura
Crawfish	Macrura
Croaker	Sciaenidae
Cutlassfish	Trichiuridae
Cuttlefish	Sepioidea
Dorado	*Coryphaena* spp.
Drum	Sciaenidae
Dungeness crab	*Cancer magister*
Filefish	*Navodon septentrionalis*, *S. modestus*
Flatfish	Pleuronectiformes
Flounder	Pleuronectidae
Flyingfish	Excoetidae
Frigate tuna	*Auxis thazard*
Gizzard shad	Dorosomidae
Goatfish	Mullidae
Golden banded fusilier	*Caesio chrysozona*
Greenland turbot	*Reinhardtius hippoglossoides*
Grunt	Pomadasyidae
Haddock	*Melanogrammus aeglifinus*
Hairtail	*Trichiurus haumela*
Halibut	Pleuronectidae
Harvestfish	*Stromateoides nazawae*

Appendix Table 1.--Continued.

English name	Scientific name
Hemiramph	Hemiramphidae
Herring	Clupeidae
Horse mackerel	*Trachurus japonicus*
Indo-Pacific mackerel	*Rastrelliger* sp.
Jack	Carangidae
Jack mackerel	*Engraulis japonica*
Jewfish	Epinephelidae
King crab	*Paralithodes camtschatica*
Large yellow croaker	*Pseudosciaena crocea*
Laver	Rhodophyceae
Lizardfish	*Saurida* spp.
Mackerel	Scombridae, Carangidae
Mackerel scad	*Decapterus macarellus*
Mahimahi	*Coryphaena hippurus*
Marusoda	*Auxis rochei*
Menhaden	*Brevoortia* spp.
Milkfish	*Chanos chanos*
Mullet	Mugilidae
Nenipterid	Nemipteridae
Octopus	Octopodidae
Opelu	*Decapterus* spp.
Oyster	Ostreidae
Pacific round herring	*Etrumeus teres*
Parrotfish	*Scarus* spp.
Paste shrimp	*Acetes chinensis*, *A. japonicus*
Perch	Embiotocidae
Pink salmon	*Onchorhynchus gorbuscha*
Pomfret	Stromateidae
Porgy	*Sparus* sp.
Prawn	*Pandalus platyceros*, *Penaeus orientalis*, *P. chinensis*
Purple pike conger	*Muraenesox cinereus*
Red sea bream	*Chrysophrys major*
Red squid	*Ommastrephes bartramii*
Ray	*Rajida* sp.
Round herring	*Dussumieria acuta*
Round scad	*Decapterus maruadsi*
Sailfin sandfish	*Arctoscopus japonicus*
Salmon	Salmonidae
Sand lance	*Ammodytes personatus*
Sardine	Clupeidae
Saury (Pacific)	*Cololabis saira*
Scallop	Pectinidae
Sea bass	Serranidae
Sea bream	Sparidae
Sea cucumber	Holothuroidea
Sea mussel	Mytilidae

Appendix Table 1.--Continued.

English name	Scientific name
Sea sheat	*Plotosus anguillaris*
Sea slug	Nudibranchia
Sea urchin	Echinoidea
Shad	Dorosomidae
Shark	Chondrichthyes
Shrimp	Macrura
Siganids	Siganidae
Sillaginoid	Sillaginidae
Silver whiting	*Silago* spp.
Skipjack tuna	*Katsuwonus pelamis*
Slipmouth	Leiognathidae
Small yellow croaker	*Pseudosciaena polyactis*
Snapper	Lutjanidae
Sockeye salmon	*Oncorhynchus nerka*
Sole	Pleuronectidae
Spanish mackerel (Japanese)	*Scomberomorus niphonius*
Spiny lobster	Palinuridae
Squid	Teuthoidea
Steelhead trout	*Salmo gairdneri*
Swimming crab	Portunidae
Swordfish	*Xiphias gladius*
Thornyhead	Scorpaenidae
Threadfin	*Polydactylus sexfilis*
Threadfin bream	*Nemipterus* spp.
Threeline grunt	*Plectorhynchus cinctus*
Thresher shark	*Alopius vulpinus*
Trout	Salmonidae
Tuna	Scombridae
White seabass	*Synoscion nobilis*
Wrass	Labridae
Yellowfin tuna	*Thunnus albacares*
Yellowtail	*Seriola quinqueradiata*

DISTRIBUTION AND MIGRATION OF FLYING SQUID, *OMMASTREPHES BARTRAMI* (LESUEUR), IN THE NORTH PACIFIC

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ABSTRACT

Mantle length, surface temperature, and catch and effort data gathered from 1980 to 1983 in the Korean drift gill net fishery were examined to determine seasonal distribution and migration of flying squid, *Ommastrephes bartrami* (LeSueur), in the North Pacific.

Flying squid was taken by commercial fishing vessels in waters with surface temperatures ranging from 9° to 22°C. The best fishing occurred in water temperature of 15°-16°C in May through July and between 13° and 18°C in August through January. High densities of flying squid were found in thermal fronts of 18°C in August and 15°C in September. The densities of flying squid in the western North Pacific were higher than in the central North Pacific. The high densities of flying squid in the western North Pacific were attributed to the high gradient of oceanographic properties in the region.

Mantle length measurements of flying squid indicated dominant modes at 38-39 cm in the central North Pacific from June to July and at 30-31 cm in the northwestern Pacific from September to December.

The migration of flying squid in the North Pacific was hypothesized from observations of the monthly distributions of catch per unit effort, mantle length measurements in statistical blocks, and hydrographic features. Large squid appeared in the northern central Pacific region earlier than small squid during the northward migration period (from June to August). The southward migration from the subarctic frontal zone began in autumn, as waters cooled with the development of the Oyashio. Large squid started its southward migration from more northern waters than small squid but reached the spawning grounds ahead of the smaller squid.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

INTRODUCTION

The flying squid, Ommastrephes bartrami, LeSueur, has worldwide distribution in subtropical and temperate oceanic waters (Young 1972; Okutani 1973; Roper et al. 1984). The annual catches of this species in the North Pacific by Japan, Korea, and Taiwan averaged about 300,000 metric tons (MT) in recent years. Exploratory fishing in the North Pacific by Korean drift gill net vessels began in 1979 and by the 1983 season, about 100 vessels were operating in the area.

Even though there are many reports describing the distribution and movement of flying squid in the northwestern Pacific, mostly by Japanese scientists (Murakami 1976; Murata et al. 1976, 1981, 1983a, 1983b; Murata and Ishii 1977; Naito et al. 1977a, 1977b; Murakami et al. 1981; Kubodera et al. 1983), the reports do not contain information on the seasonal distribution and migration routes of the squid in the central North Pacific.

This study (1) examines the seasonal distribution and migration of flying squid in the North Pacific based on density distribution, oceanographic conditions, and body size composition of squid taken in the Korean drift gill net fishery from 1980 to 1983 and (2) develops a migration model of flying squid in the North Pacific Ocean.

MATERIALS AND METHODS

During the 1980-83 fishing seasons, about 207 Korean gill net vessels operated in the North Pacific. Of this total, 132 vessels provided 871 vessel-month catch and effort data. Vessel sizes ranged from 150 to 500 gross tons (GT), and half of them were in the 200-300 GT range. Each unit of gill net was 50 m long and 8 m deep (Table 1, Fig. 1), with mesh sizes ranged from 96 to 115 mm. The average number of gill nets used by one vessel per day was 200 in 1980 and 540 in 1983 (Table 2).

Annual and monthly catch per unit effort (CPUE) in kilograms per net were calculated for each statistical block (1° of latitude by 1° of longitude) corresponding with the format used by the Deep Sea Resources Research Division of the Korean National Fisheries Research and Development Agency for recording daily catches. Monthly dorsal mantle length (DML)

Table 1.--Details of the Korean flying squid gill net (mesh 0.497 mm).

Mesh size (mm)	Length of float line (m)	Hanging ratio		Depth of net (m)	Net
		Upper	Lower		
96	50	0.446	0.457	8.79	Nylon monofilament 0.497 mm.
105	50	0.446	0.454	8.74	Do.
110	50	0.459	0.470	12.30	Do.
115	50	0.461	0.471	7.80	Do.

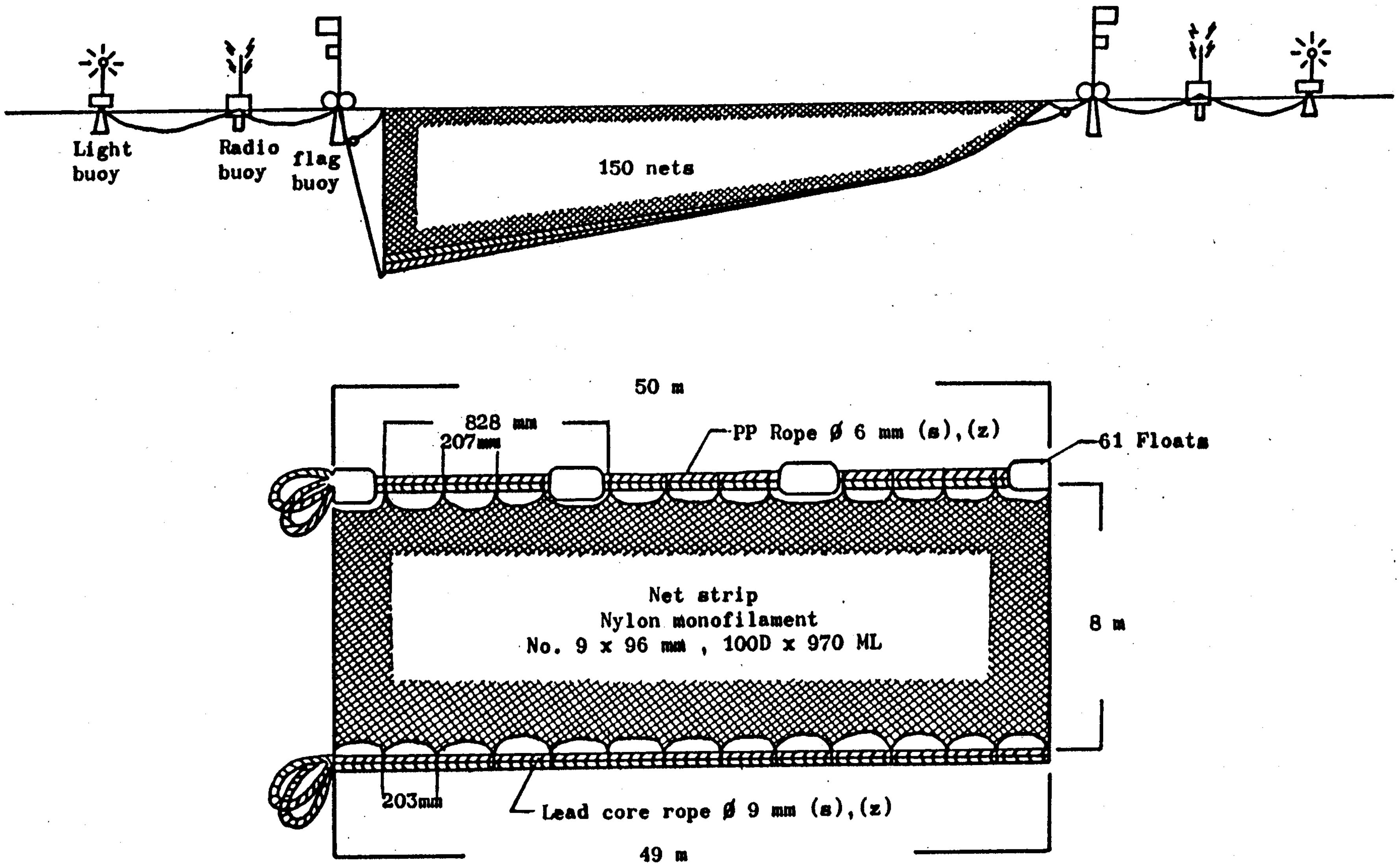

Figure 1.--Schematic diagram of the Korean flying squid gill net in the North Pacific.

Table 2.--Annual fishing effort, catch and catch per unit effort in the Korean flying squid gill net fishery in the North Pacific, 1980-83 by metric tons (MT) (parentheses indicate number of vessel-months).

Year	No. of vessels registered	No. of vessels sampled	No. of days fished	No. of gill net units	Catches by sampled vessels (MT)	Average No. of gill nets per vessel-month	Average No. of gill nets per vessel-day	Catch per vessel-month (ton/vessel-month)	Catch per unit net (kg/net)
1980	14	9 (44)	684	139,638	3,017.3	3,173.6	204.1	68.6	21.6
1981	34	9 (73)	1,374	194,060	6,061.6	5,398.1	286.8	83.0	15.4
1982	60	56 (327)	6,375	2,733,635	21,371.3	8,359.7	428.8	65.1	7.8
1983	99	56 (419)	7,560	4,070,372	27,130.5	9,714.5	538.4	64.8	6.7
Total or average	207	130 (871)	15,379	7,337,705	57,341.8	8,424.5	477.1	65.8	7.8

compositions were obtained for each 1° of latitude by 5° of longitude block.

The optimum temperature for flying squid fishing was calculated as a weighted mean of catch and surface temperatures in each statistical block having both temperature measurement and fishing record. Catch per unit effort for statistical blocks was plotted together with the surface thermal structure derived from the NOAA Satellite infrared data from the northwestern Pacific (Japan Fisheries Information Service Center 1983).

Based on the analyses of CPUE and temperature, an attempt was made to describe the density distribution and migration by size group of flying squid in the North Pacific.

RESULTS

Distribution of Catch Per Unit Effort

The distribution of annual CPUE (kilograms per net) by statistical block (1° of latitude by 1° longitude) for the Korean flying squid gill net fishery in the North Pacific from 1980 to 1983 is shown in Figure 2. The fishing grounds are found in the region of lat. 30°-45°N and long. 143°E-180° in 1980 and lat. 34°-46°N and long. 142°E-179°W in 1981. The fishing grounds expanded to the central North Pacific east of long. 170° and 165°W in 1982 and 1983, respectively. The number of statistical blocks with high CPUE's in the same region west of 180° tended to decrease in succeeding years from 1981 to 1983. The distribution of monthly CPUE by statistical block in the 1983 season is shown in Figure 3. The number of blocks having CPUE's higher than 6 kg/net increased in succeeding months from May to July in the area lat. 35° to 40°N and long. 150°E to 165°W. In August, the fishing grounds were formed north of lat. 40°N and the center of the grounds was farther to the west between long. 150° and 165°E in the northwestern Pacific. In September, the fishing grounds extended from Hokkaido to long. 165°E, and the eastern limit of the fishing ground moved gradually westward in subsequent months through December and January. The centers of fishing grounds thus tended to shift to the north by 2° or 3° in succeeding months from May to July in the central North Pacific, then west to off Hokkaido in August and September, and to south off northern Honshu in subsequent months through January.

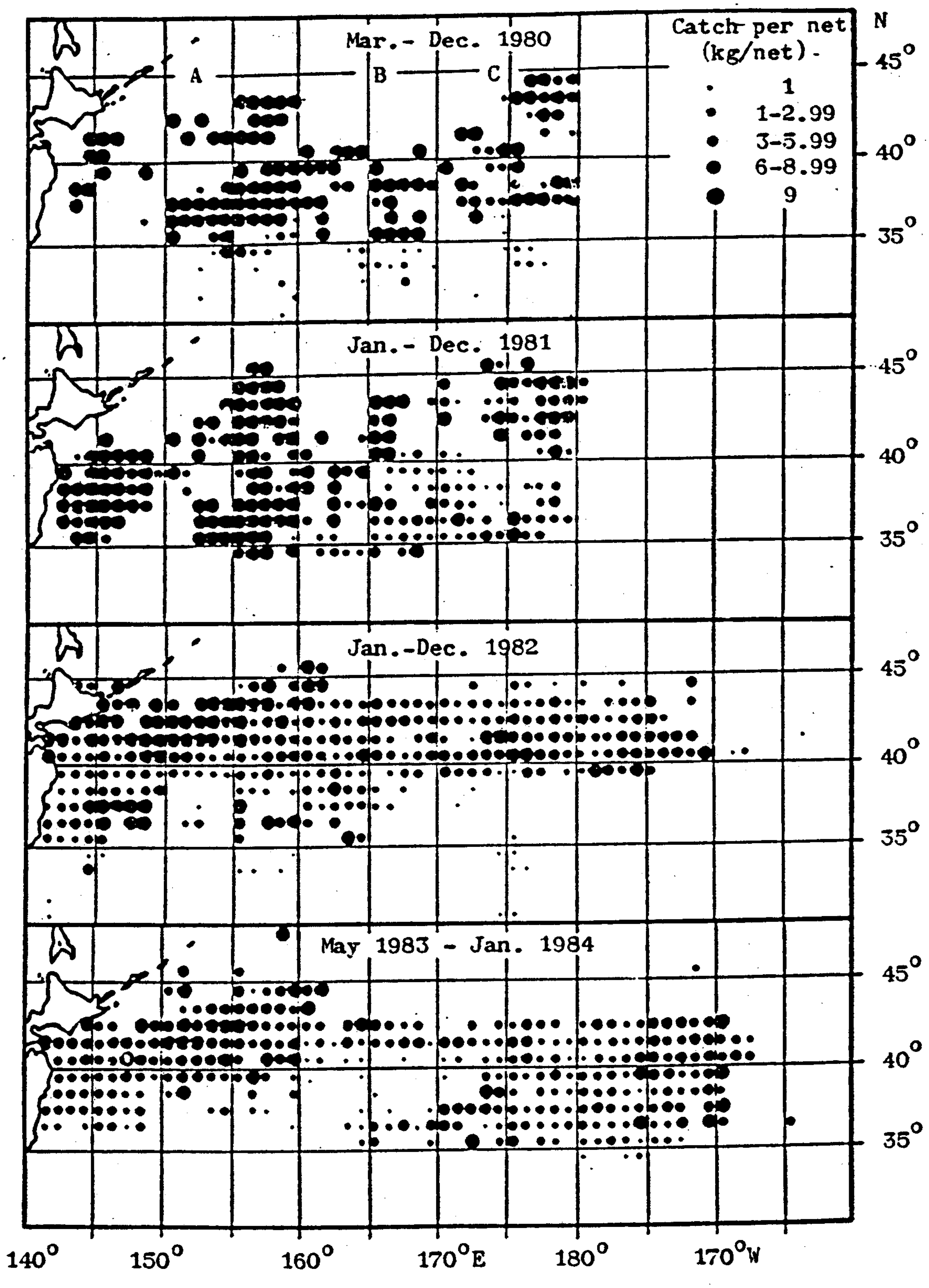

Figure 2.--Annual flying squid catch per unit net (kilograms per net) plotted by 1° squares in the Korean gill net fishery in the North Pacific from 1980 to 1983.

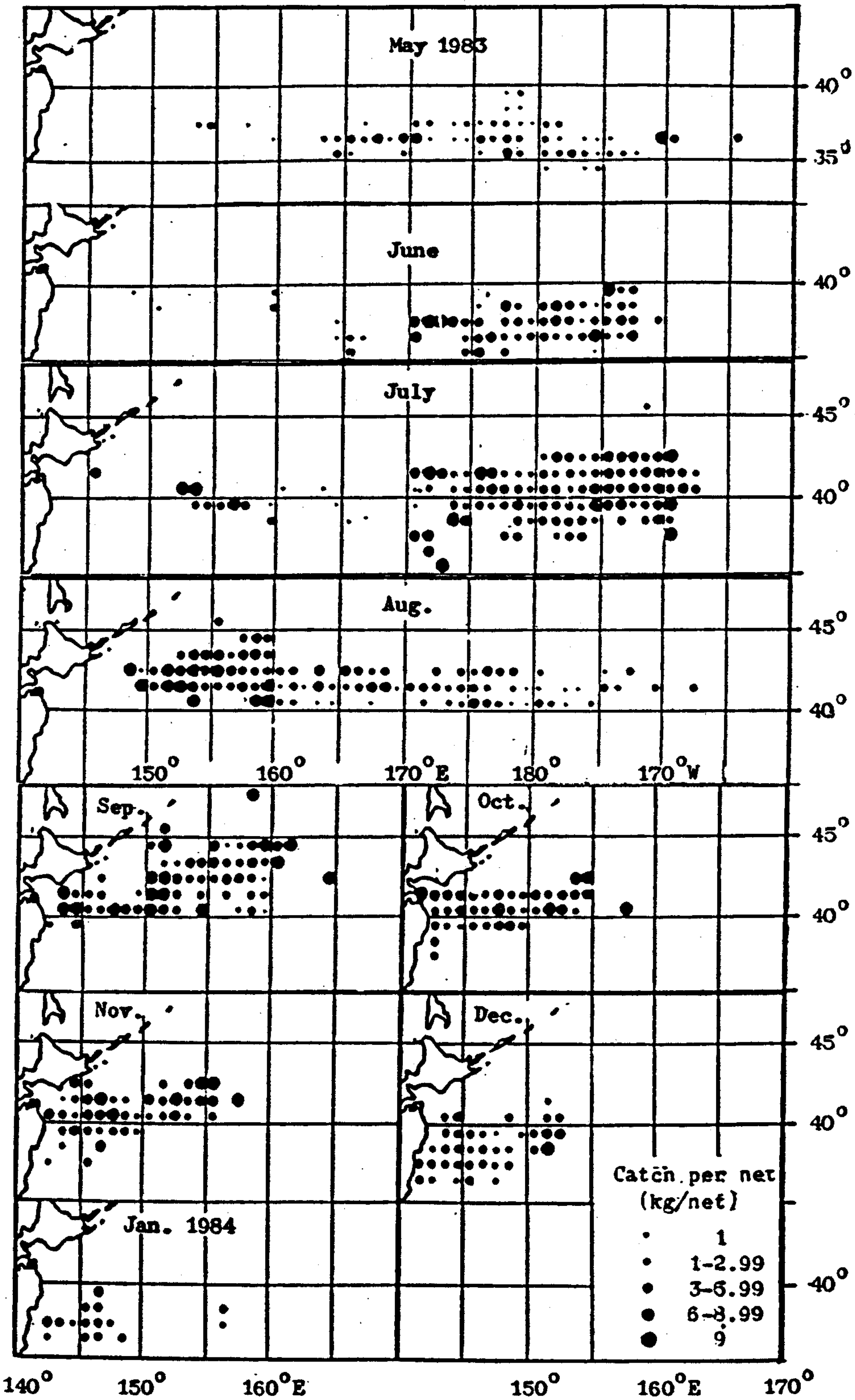

Figure 3.--Monthly flying squid catch per unit net (kilograms per net) plotted by 1° square in the Korean gill net fishery in the North Pacific from May 1983 to January 1984.

Monthly catches by 1° of longitude in the 1983 season are shown in Figure 4. In June and July the peak catch was located in the area east of long. 170°E, and the peak showed the trend gradually shifting westward from August to December except for November.

Monthly CPUE by 1° of longitude in the 1983 season is shown in Figure 5. In May CPUE's were high in the region along long. 170°W. In June and July CPUE's were quite high in the region along long. 170°E. In August, CPUE's were high in the region west of long. 160°E. From September through November high CPUE's were found in the area around long. 155°-165°E. Through the whole fishing season the area west of long. 160°E had slightly higher CPUE's than the area east of long. 160°E. However, there were no significant differences by area in distribution of CPUE's than there were in distribution of catches.

Catches Relative to Surface Thermal Structure

Monthly changes in frequency of catch of flying squid and surface temperature at the locations where Korean gill net vessels operated in the North Pacific are shown in Figure 6. The range of surface temperatures for commercial fishing of squid was 9°-22°C. The water temperature for the best fishing ranged from 15° to 16°C in May through July and from 13° to 18°C in August through January. The higher densities of flying squid were found in thermal fronts along the 18°C isotherm in August and the 15°C isotherm in September (Fig. 7).

Mantle Length Compositions of Flying Squid

Monthly DML measurements (sexes combined) in the 1983 season (Table 3) indicate four size groups in the catches: small (<25 cm), medium (27-32 cm), large (35-39 cm), and extra large (>40 cm). The dominant modes were at 38-39 cm in region C east of long. 170°E from June to July, and at 30-31 cm in region A west of long. 140°E from September to December.

The monthly frequency distributions of DML (Fig. 8a) indicate that in June large squid were present in the area south of lat. 39°N and medium-sized squid in the area north of lat. 39°N. From July to September large squid were found in the northern area while small squid were in the southern area. Large squid with modal lengths of 40 cm were found at lat. 41°-43°N in October and lat. 39°-40°N in November. The proportion of large squid decreased in the area south of lat. 38°N in December.

Frequency distributions of flying squid by 5° of longitude in the 1983 season are shown in Figure 8b. Generally, large squid occurred more commonly in the eastern areas from May to October, whereas medium-sized squid were more commonly found in the western region from November to December.

DISCUSSION

Exploitation of Flying Squid and Fishing Methods

Flying squid have been caught in the North Pacific in the Japanese squid jigging fishery since 1974 and in the drift gill net fishery since

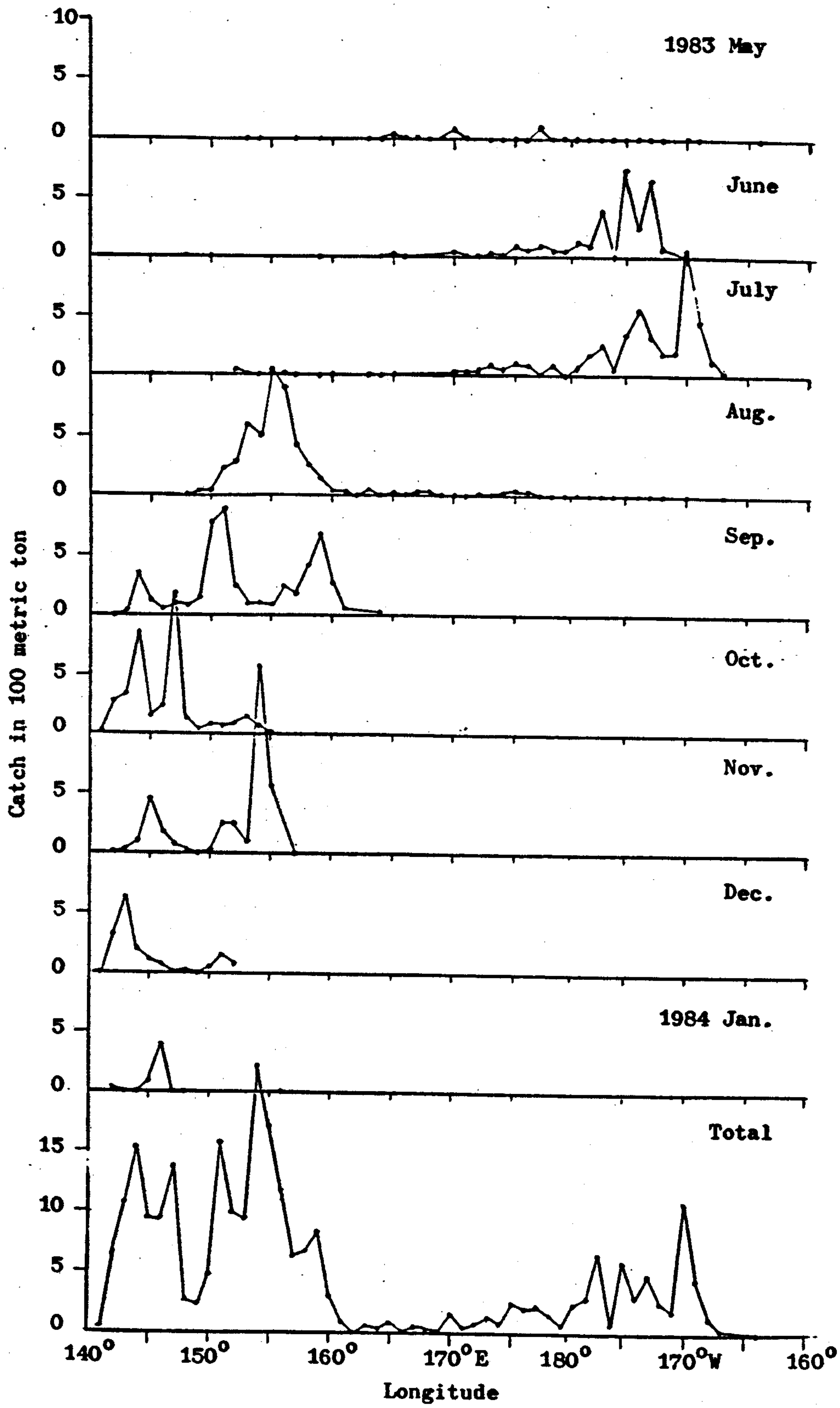

Figure 4.--Catch of flying squid by 1° of longitude in the Korean flying squid gill net fishery in the North Pacific, May 1983 to January 1984.

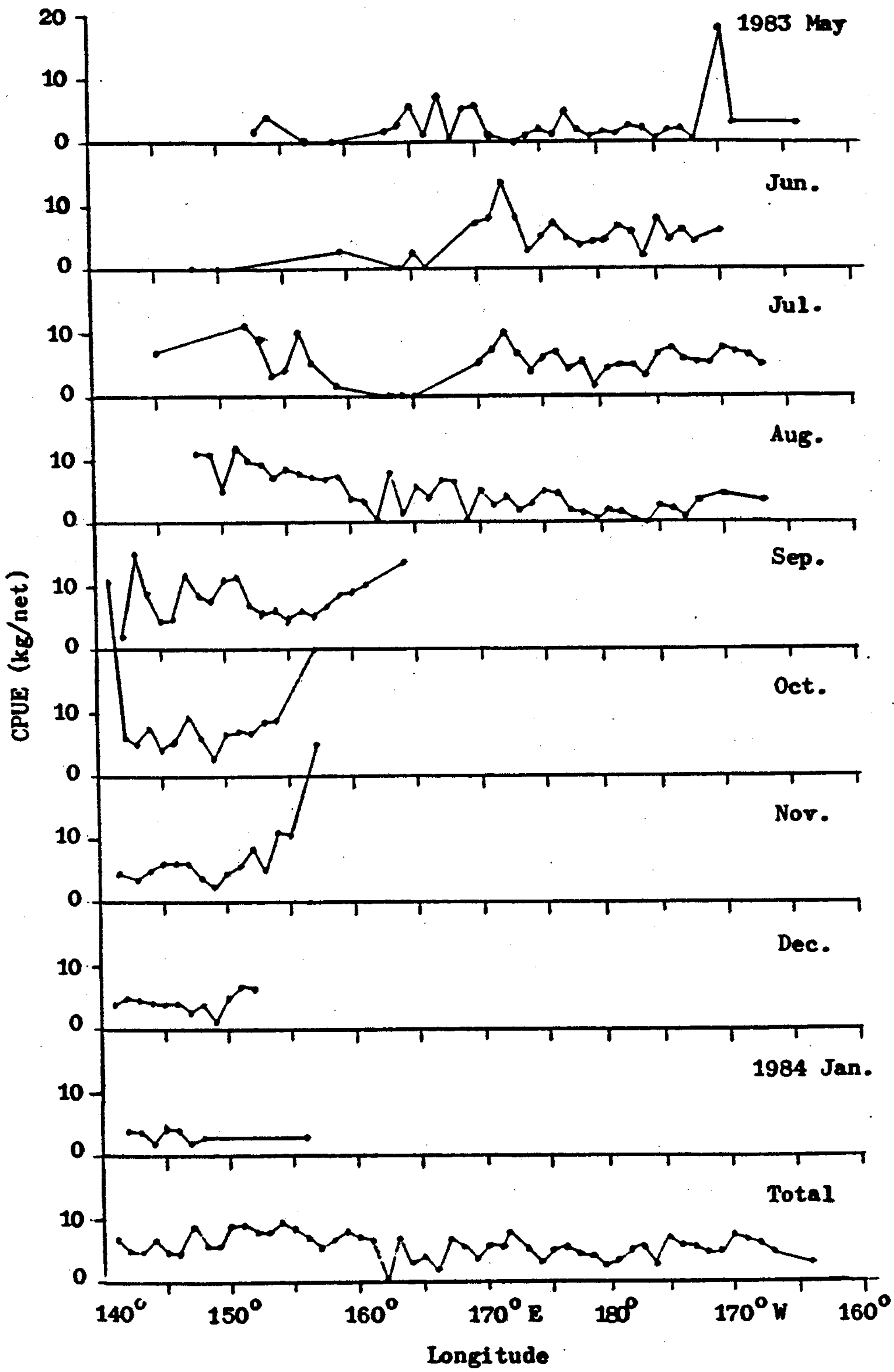

Figure 5.--Catch per unit effort of flying squid by 1° of longitude in the Korean gill net fishery in the North Pacific, May 1983 to January 1984.

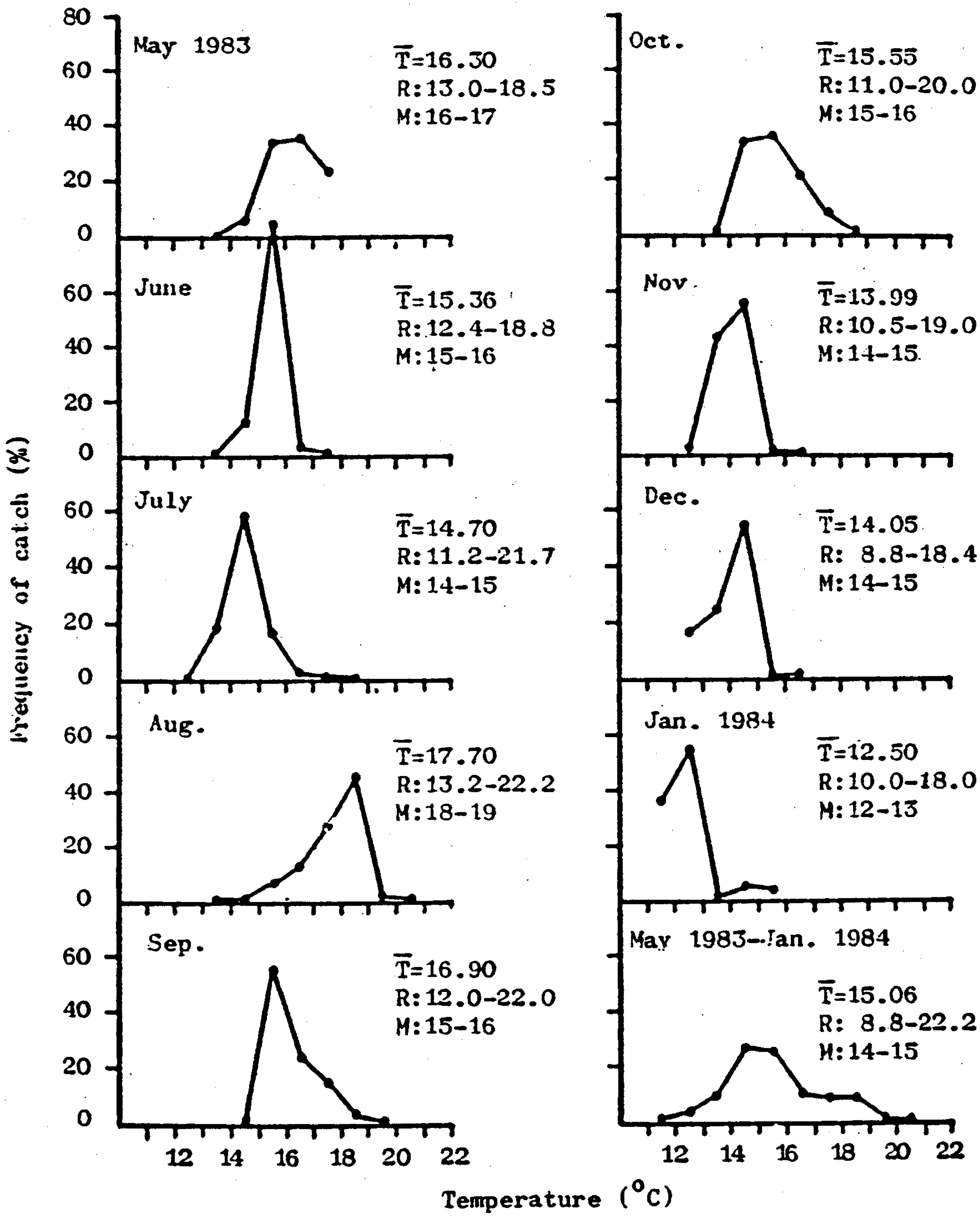

Figure 6.--Monthly plots of frequency of catches and surface water temperatures (°C) in the Korean gill net squid fishery, May 1983 to January 1984 (T = weighted mean temperature (°C); R = temperature range; M = mode).

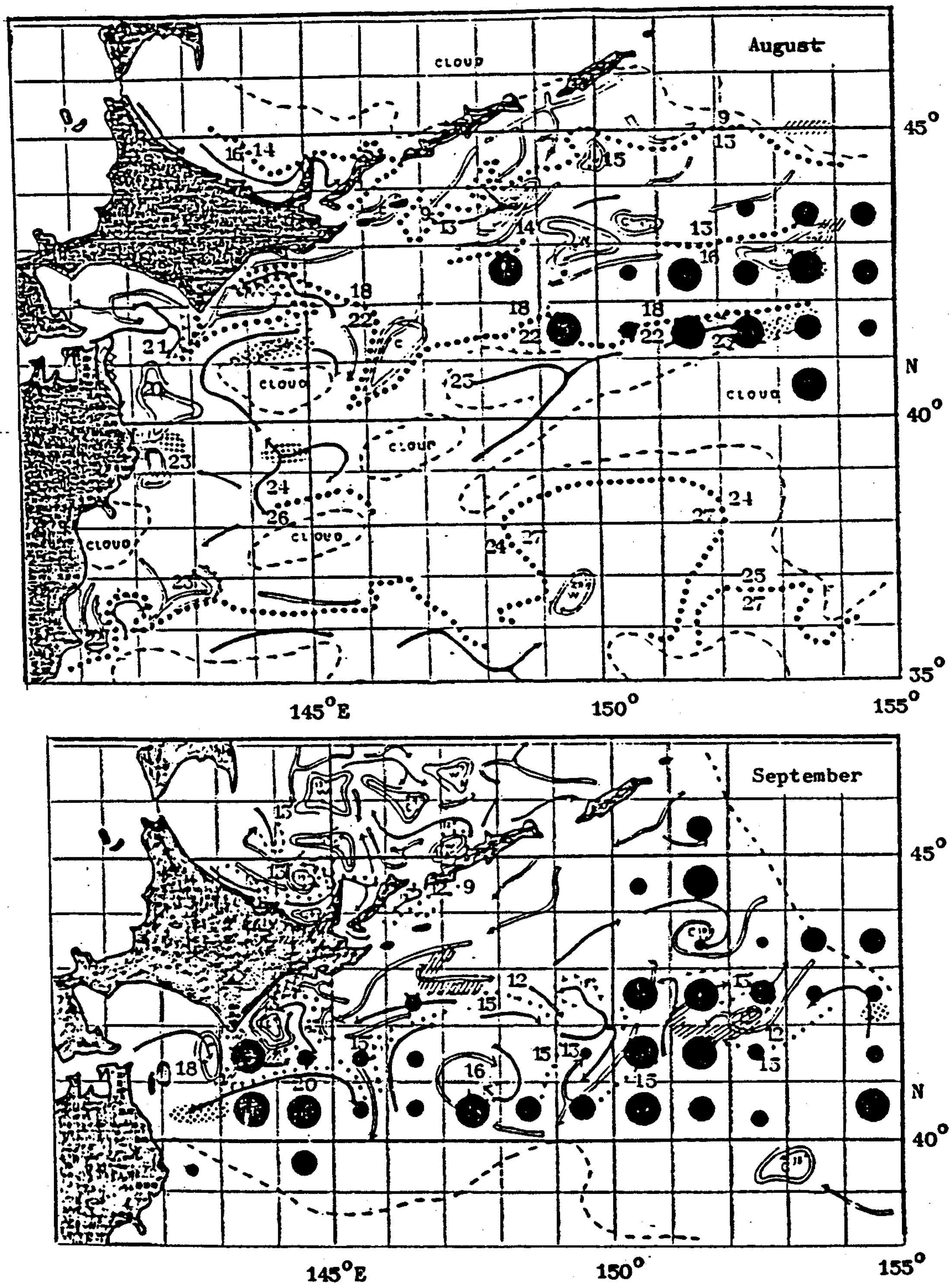

Figure 7.--Surface thermal structure based on infrared imagery from meteorological satellites of the National Oceanic and Atmospheric Administration and the catch per unit net of flying squid by statistical block (1° of latitude by 1° of longitude) from the Korean gill net fishery in the northwestern Pacific in August and September 1983. Thermal structure traced from Japan Fisheries Information Service Center (1983). Dark circle denotes catch per unit net. Small dotted lines denote the thermal fronts. Figures denote temperature in degrees Celsius.

Table 3.--Monthly modes of dorsal mantle lengths of both sexes of flying squid from the Korean gill net fishery in the North Pacific 1983 fishing season (S = small; M = medium; L = large; LL = extra large squids).

Month/ year	No. of samples	Modal length (cm)[1]							Main fishing area[2]
		S	M		L		LL		
May 1983	143	25	29	32	35	38	11	--	B,C
June	638	--	28	32	--	39	--	--	C
July	698	--	--	32	--	38-39	12	--	C
Aug.	639	25	--	32	35	--	40	--	A,B,C
Sept.	635	--	--	30	36	--	--	--	A
Oct.	718	25	--	30	35	--	40	--	A
Nov.	590	--	29	31	--	39	--	--	A
Dec.	569	--	--	31	35	--	40	--	A
Jan. 1984	217	22	27	31	--	--	43-45	49	A
Modes	4,847								

[1]A = west of long. 160°E; B = long. 160°-170°E; C = east of long. 170°E.

[2]Numbers underlined indicate the most dominant mode.

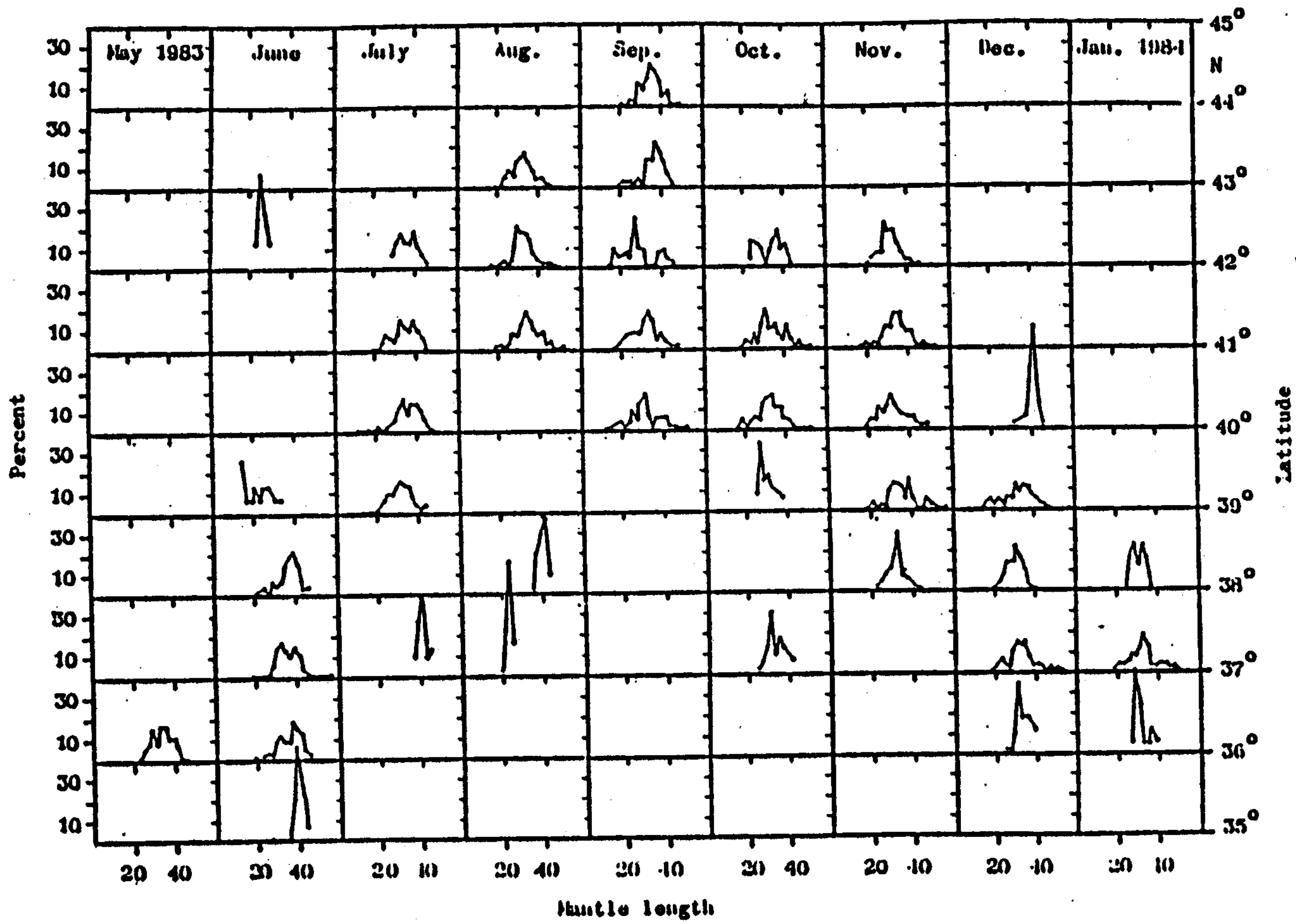

Figure 8a.--Monthly mantle length-frequency distributions of flying squid taken in the North Pacific Korean gill net fishery, May 1983 to January 1984, plotted in 1° of latitude.

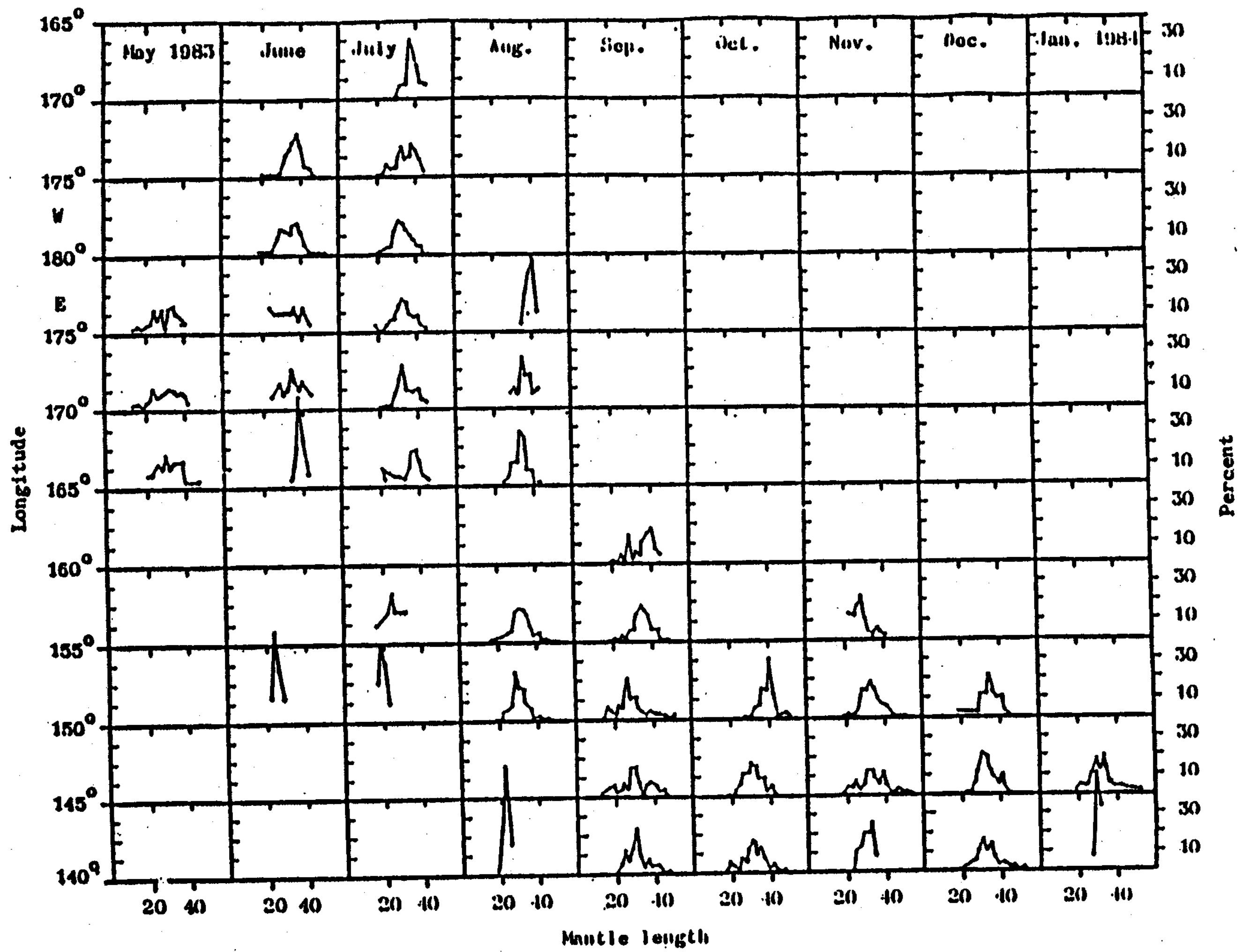

Figure 8b.--Monthly mantle length-frequency distributions of flying squid taken in the North Pacific Korean gill net fishery, May 1983 to January 1984, plotted in 5° of latitude.

1978 (Akabane et al. 1979; Kubota and Yasui 1980; Murata et al. 1980, 1981, 1982, 1983a, 1983b, 1984; Suisan Sekai 1982; Ogura 1984). With the decline of the stock of Todarodes pacificus in the Sea of Japan and with the economic difficulties in the tuna longline fishery, Korean gill net vessels, mostly converted tuna longliners, have increasingly shifted their efforts to the exploitation of flying squid in the North Pacific. Since 1982 catch and effort levels for this species have gone well beyond the exploratory stage. The catch of 54 monitored vessels was 27,131 MT in 1983 (Table 2). Projecting this catch for the 99 vessels registered for fishing in 1983 would yield a total of about 48,000 MT for the season.

The Korean gill net fishing grounds have extended eastward each year since 1979 and reached as far east as long. 161°W in 1983 (Fig. 2). The fishing season lasted about 9 months from May through January with peak catches occurring from July to November (Gong et al. 1984). As shown in the monthly distribution of CPUE, the center of the Korean gill net fishing grounds tended to move from east to west in succeeding months during the 1983 fishing season (Fig. 3).

Korean vessels usually began fishing at 1500 or 1600 with the setting of the nets. Setting was done at vessel speeds of 5 or 6 knots and was usually completed in 2 or 3 h. Net hauling began at 0200 or 0300, after 7 or 8 h of soaking, and was completed in about 8 h. Each set consisted of about 200-250 nets of varied mesh size in summer and 150 or 200 nets in winter. During the 1983 season the number of gill nets used averaged 540 per vessel per day.

Life History of Flying Squid

Ommastrephes bartrami has transoceanic distribution in the subtropical and temperate region of the North Pacific Ocean from Japan to North America (Young 1972; Okutani 1973; Naito et al. 1977a, 1977b; Baba and Akabane 1980; Murata et al. 1981, 1983b; Murakami et al. 1981; Ogura 1984). Recently it was reported that this species also occurred in the eastern Sea of Japan (Kasahara 1984; Sato et al. 1984).

Based on geographically separated spawning grounds, some authors (Baba and Akabane 1980; Murata et al. 1980, 1981, 1982) divide the flying squid into two groups: the northwestern Pacific (west of long. 170°E) and the central North Pacific. However, it is difficult to separate the population into two groups because the CPUE is rather high around long. 170°E based on the Korean gill net fishery.

The spawning season of the flying squid extends from January to May, and it has been reported that spawning occurs in Kuroshio waters south of lat. 35°N and west of 155°E. Considering the broad area of the Korean gill net fishery in winter and spring (Figs. 2, 3), it appears that the spawning grounds of flying squid would extend farther eastward in the central North Pacific.

The flying squid is known to undergo wide migrations. Baba and Akabane (1980) show that the species migrates northward early in the season and turns westward in the fall. It is possible to distinguish fast-growing and slow-growing groups. The former occurs earlier in the northern area than the latter (Murakami 1976; Murata and Ishii 1977; Roper et al. 1984). Naito et al. (1977b) and Murakami et al. (1981) reported that large squid always appear ahead of small squid during both the northward and southward migrations and that large squid are distributed farther offshore than small squid.

The monthly mantle length compositions from Korean catches show that large squid appear in the northern area earlier and are distributed farther eastward than small squid (Fig. 8a, 8b). However, it is noted that this is not always true.

Ishii (1977), Murata and Ishii (1977), and Tamura and Nakata (1983) believe that the flying squid spawns from late autumn to winter and the lifespan is 1 year. However, Murakami et al. (1981) and Kubodera et al. (1983) stated that large squid over 40 cm are 2-year olds.

Oceanographic Structure and Density Distribution of Flying Squid

There are many reports on water temperature in the northwestern Pacific flying squid fishing grounds (Murata and Araya 1970; Murakami 1976; Murata et al. 1976, 1980, 1983a, 1983b, 1984; Naito et al. 1977a, 1977b; Kubodera et al. 1983; Amano et al. 1984). However, none of these relate oceanographic conditions to fishery data. Kawakami (1983) reviewed the temperature range and optimum temperatures for squid fishing in the Kuril Front region. According to his report the range of water temperatures in which flying squid were caught throughout the fishing season in the North Pacific was 6°-24°C, and the higher catches were in 15°-20°C water. Kubodera et al. (1983) reported that seasonal changes in distribution and abundance of *Ommastrephes bartrami* appeared to be closely correlated with surface water temperature. Sea surface temperatures in the Korean drift gill net fishing grounds west of long. 161°W ranged from 9° to 22°C, and the most favorable temperature for flying squid fishing was 15°C (Fig. 6).

Kubodera et al. (1983) indicated that the thermal front and salinity front in the Subarctic Boundary Zone could be barriers to flying squid in the northward migration. The northern limit of the Korean flying squid gill net fishing ground reached the Subarctic Domain in autumn. The horizontal gradients of temperature and salinity in the Subarctic Boundary were higher in the west than the east (Muromtsev 1958; Dodimead et al. 1963; Favorite et al. 1976). It is easy to understand why the density of flying squid would be higher in the west than the east based on oceanographic features.

Migration Model of Flying Squid in the North Pacific

A migration model for flying squid is hypothesized based on the monthly distribution of abundance indices, monthly mantle length compositions by statistical block, and the hydrographic features of the North Pacific (Fig. 9).

As shown above from the horizontal distribution of oceanographic characteristics, the oceanic structure of the North Pacific is divided into

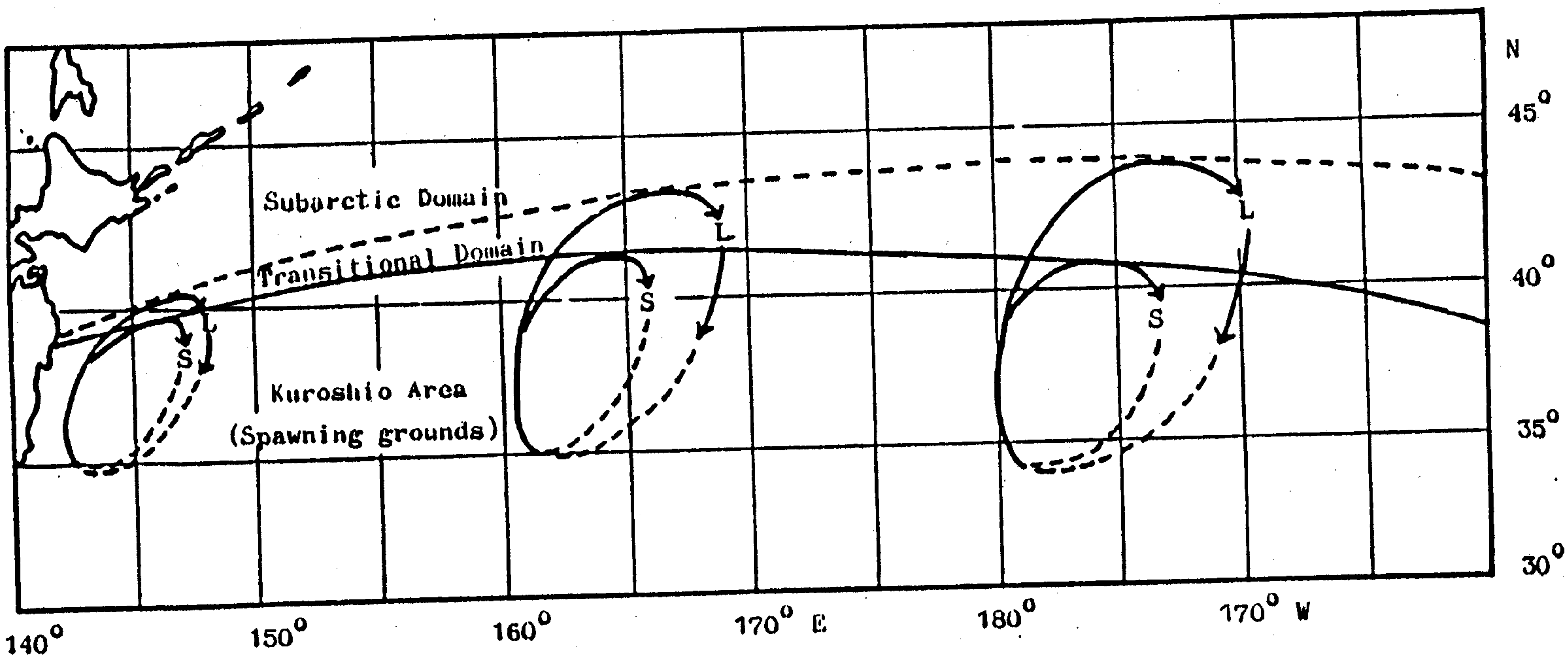

Figure 9.--Hypothetical migration routes by size groups of flying squid in the North Pacific. Full line denotes the Subarctic Boundary and dashed line the salinity front. L denotes the large sized group and S the small sized group of flying squid. Dashed lines in the migration circuit indicate the period of southward migration at the subsurface layer.

three different waters. The farther westward, the narrower the Transitional Domain and the higher the horizontal gradient of oceanographic characteristics. Based on monthly mantle length composition of flying squid captured by the Korean gill-netters, by grids of 1° of latitude by 5° of longitude, groups of large flying squid occurred more frequently in the northern and eastern areas of the fishing grounds. Naito et al. (1977a) indicated that the larger squid migrate faster and move ahead of the smaller squid during the northward and southward migration periods. In the beginning of the migration all groups start to migrate at the same time. However, the group of large squid starts to move southward from the north while the group of small squid starts to move from the south. In the fishing grounds, the larger squid move ahead of the smaller squid during the southward migration period. Accordingly, the group of large squid group does not always move ahead of the group of small squid everywhere in the North Pacific.

The flying squid which are spawned south of the Subarctic Boundary in winter carry out a northward migration in the warmwater system of the Kuroshio and grow relatively fast in spring and summer. The first born and faster growing squid of the large group enter the Transitional Domain after passing the thermal front in the Subarctic Boundary, but they are prevented from migrating farther north by the salinity front between the Transitional and Subarctic Domain. On the other hand the slow growing squid of the small group become concentrated in the thermal front. They begin the reverse southward migration in autumn with the onset of cooling and the development of the Oyashio. The large group start to return from the northern area and the small group from a more southern area, but the former reach the spawning ground earlier because they move ahead of the small group during the migration. The density of flying squid in the northwestern area is higher than that in the central North Pacific area because the gradient of oceanographic properties in the west is higher than in the east. Distances between oceanographic boundaries are narrower and the size of migration circuits smaller in the northwest than in the central areas as shown by the migration model (Fig. 9).

The general pattern of movement and migration of flying squid is clockwise in the North Pacific. However, the monthly movement of the center of the Korean drift gill net fishing grounds was counterclockwise.

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NET LOSS FROM TRAWL FISHERIES OFF ALASKA

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ABSTRACT

The most dominant fisheries off Alaska in terms of geographical extent, seasonal duration, and volume of catch is the trawl fishery for groundfish. This fishery began in earnest in 1954, mainly by foreign nations which now number seven, and only recently has been joined by domestic trawlers. The number of foreign trawlers increased rapidly to more than 400 vessels by 1963 and fluctuated around 300 vessels until 1975. Since then, the number of foreign vessels has decreased gradually. Domestic trawlers have remained small by comparison in numbers and physical size. However, expansion of the domestic trawl fleet has been rapid, from just a few vessels in 1979 to 93 in 1984. The total fleet size has, therefore, remained above 300 vessels. This paper traces the progression of these trawl fisheries by two regions--the Bering Sea-Aleutians region and the Gulf of Alaska region. Estimates are made of the number of boats and fishing effort. Effort is measured by number of vessel-months of operation. Since these trawling activities contribute to entanglement of marine mammals in active fishing gear as well as passive lost or discarded gear, the extent of net loss as a source of marine debris is estimated. These estimates are derived from data collected by the Foreign Fisheries Observer Program.

INTRODUCTION

Since the early 1960's, northern fur seal, <u>Callorhinus ursinus</u>, on the Pribilof Islands have been observed entangled in pieces of debris. Presumably this occurs as a result of encounters at sea with floating materials and the animals' behavioral attraction to this debris (Fiscus and Kozloff 1972). Studies have shown that a large portion of the animals was entangled in net debris, much of which was trawl net fragments (Fowler 1982). It was also noted that the animals are caught in large trawl net debris and that the large net fragments presented more mesh openings in which seals could become entangled.

The increased observations of entangled fur seals coincided with a period of rapid development of a large trawl fishery in the northeast

<u>In</u> R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

Pacific, particularly in the eastern Bering Sea. This fishery is now the most dominant off Alaska in terms of geographical extent, length of fishing season, amount of fishing effort, and volume of catch.

Since lost or discarded gear and other debris from the trawl fishery may contribute significantly to the entanglement of fur seals and possibly other marine mammals, it is the purpose of this paper to review the nature and extent of the trawl fishery and estimate the amount of gear that may have been lost or discarded.

HISTORY AND PROGRESSION OF FISHERIES

Historically the trawl fishery off Alaska has been predominantly foreign in origin. Japanese trawlers operated in the eastern Bering Sea during 1933-37 and 1940-41, but the major development of the foreign trawl fishery did not begin until 1954. The chronology of this development is outlined below:

1933 First commercial operations for flatfish by Japanese trawlers in the eastern Bering Sea for fish meal following explorations in 1929. The fishery was discontinued in 1937 (Fig. 1).

1940 Japan reentered the fishery with a mother ship fleet of 9 to 12 catcher vessels. Catches were mainly frozen for food. The fishery was interrupted by the second World War and terminated in 1941.

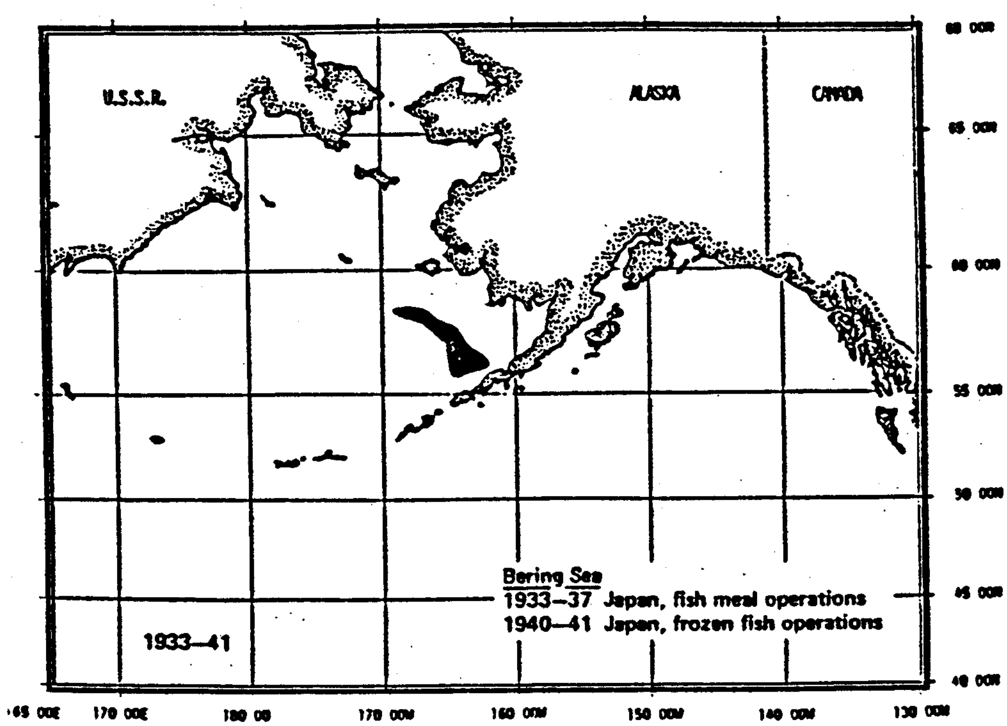

Figure 1.--Principal fishing grounds off Alaska, 1933-37 and 1940-41.

1954 Japan reentered groundfish fisheries on the eastern Bering Sea flats (Fig. 2). Flatfishes were the target species for processing into fish meal. Yellowfin sole, Limanda aspera, was the principal target species.

1959 The U.S.S.R. fishing fleets moved into the eastern Bering Sea after successful exploratory surveys in 1954 and 1958.

1961 Total catches of flatfish peaked near 610,000 metric tons (MT); yellowfin sole was apparently overharvested. Exploratory vessels were sent into the Gulf of Alaska by Japan.

1962 The U.S.S.R. started commercial operations in the Gulf of Alaska.

1963 Japan followed the example set by U.S.S.R. and moved some independent stern trawlers and longline vessels into the Gulf of Alaska which fished west of Kodiak Island.

1965 Fishing operations by Japan moved farther eastward and southward in the Gulf of Alaska.

1966 Fishing vessels of Japan and the U.S.S.R. operated along much of the North American coastline (Chitwood 1969, Fig. 3). Principal species harvested in the Gulf of Alaska were Pacific ocean

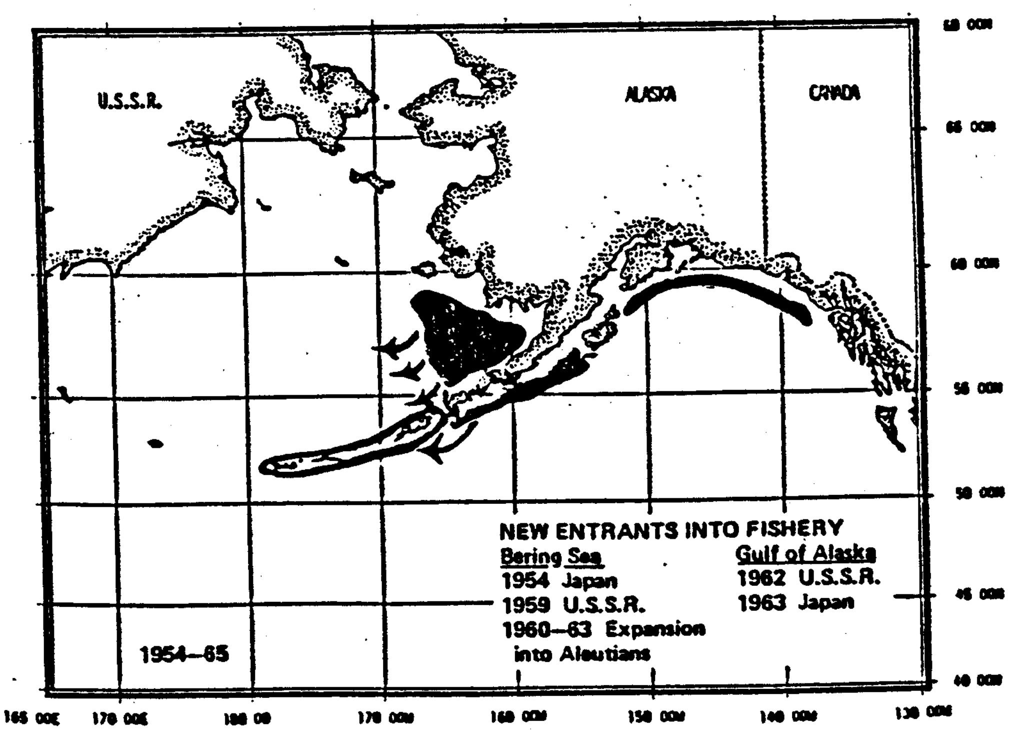

Figure 2.--Principal fishing grounds for flatfishes in the Bering Sea (1954-59) and expansion into the Gulf of Alaska (1962-65).

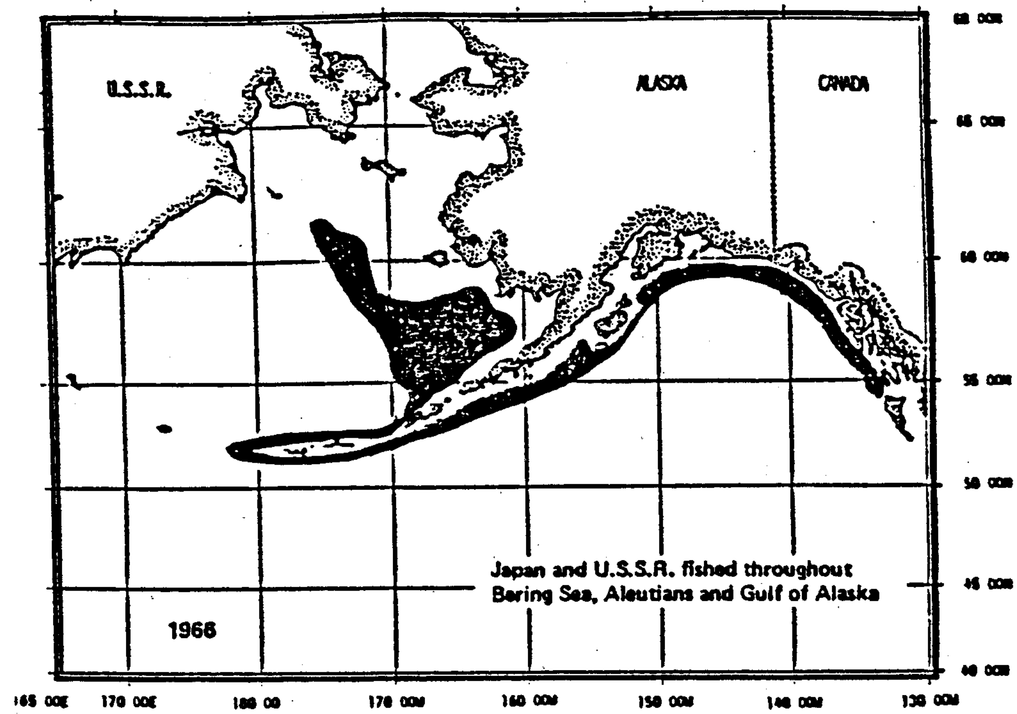

Figure 3.--Principal fishing grounds by vessels from Japan and the U.S.S.R., in the Bering Sea, Aleutians, and Gulf of Alaska in 1966.

perch, <u>Sebastes alutus</u>, and sablefish, <u>Anoplopoma fimbria</u>. In the Bering Sea, the abundance of yellowfin sole has been substantially reduced, Pacific ocean perch was being rapidly depleted, and walleye pollock, <u>Theragra chalcogramma</u>, became the prime target species as a result of introduction of automated "minced meat" processing operations aboard vessels.

1968 Trawlers from the Republic of Korea moved into the eastern Bering Sea (Fig. 4).

1974 Taiwan stern trawler initiated operations on groundfish in the eastern Bering Sea in December and a longliner fished in the Gulf of Alaska in 1975. A large stern trawler from the People's Polish Republic (Poland) entered the eastern Gulf of Alaska and targeted on Pacific cod, <u>Gadus macrocephalus</u>.

1977 The Magnuson Fishery Conservation and Management Act (Magnuson Act) was implemented which extended U.S. management jurisdiction over the fisheries resources within 200 miles of its coastline.

1978 First joint venture operation started in the Gulf of Alaska.

1979 Poland extended its fishery into the eastern Bering Sea. Mexico sent three stern trawlers to fish in the western Gulf of Alaska, but their fishery was discontinued after a short season. Regulations were enacted under the Magnuson Act to exclude foreign trawling from southeast Alaska.

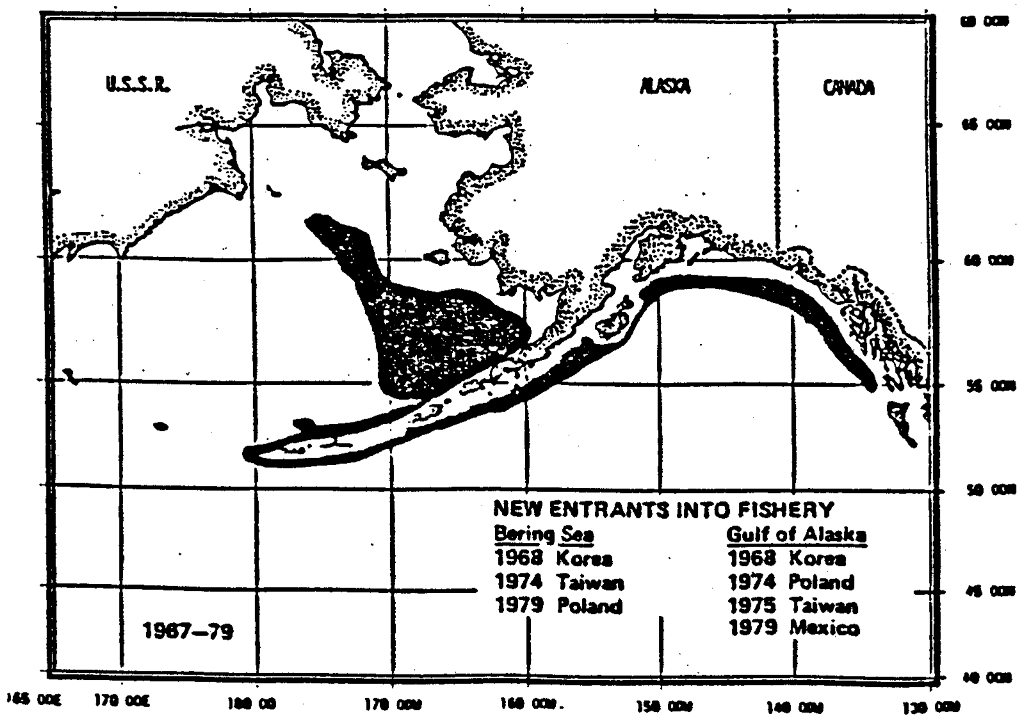

Figure 4.--Areas of groundfish fisheries off Alaska, by Japanese and U.S.S.R. vessels and those from new entrants into the fishery (Republic of Korea, Taiwan, Poland, and Mexico), in 1967-79.

1980 Joint venture fisheries started in the eastern Bering Sea and Aleutian Islands region and domestic trawling operations increased and expanded into the eastern Bering Sea, primarily for Pacific cod (Fig. 5). The U.S.S.R. was excluded from conducting a directed fishery off Alaska under regulations promulgated by the Magnuson Act. However, Soviet joint venture with United States vessels for yellowfin sole in the eastern Bering Sea and other species in the Gulf of Alaska were allowed to continue. A West German stern trawler entered into joint venture fisheries with United States vessels in the eastern Bering Sea, and this vessel was also allowed some directed fishing. As domestic fisheries developed after 1980, quotas for foreign fleets were reduced, resulting in lower fishing effort.

1982 Poland was denied permits to fish off Alaska.

1983 Taiwan did not conduct a directed fishery for groundfish but participated in joint venture operations.

1984 Joint venture and domestic fisheries had increased dramatically and were rapidly replacing foreign fishing effort. Joint ventures were conducted with processing vessels from eight countries (U.S.S.R., Republic of Korea, Japan, Taiwan, West Germany, Poland, Portugal, and Spain). Portugal entered trawl fishery in Bering Sea. The U.S.S.R. and Poland resumed trawl fisheries.

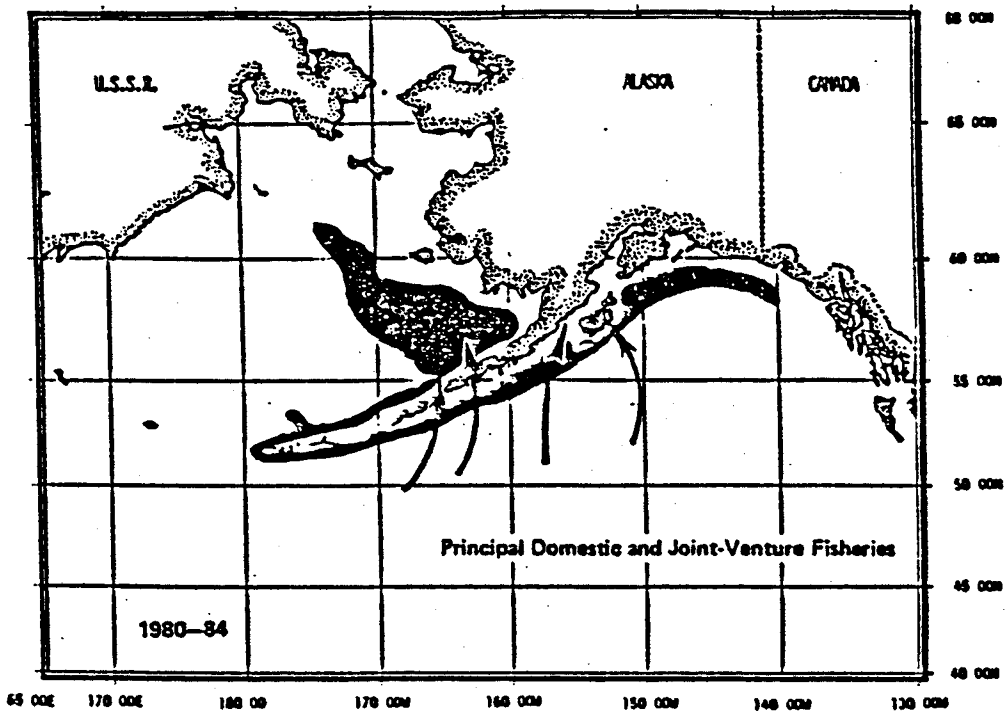

Figure 5.--Areas of U.S. domestic and joint venture trawl fisheries off Alaska in 1980-84.

In summary, eight foreign countries (besides Canada) have participated in the trawl fisheries off Alaska. Japan has had the longest history of fishing in the region and has mounted the greatest effort over the years. The U.S.S.R. had the second largest fishery until it was denied direct fishing privileges in 1980. The second position was then taken over by the Republic of Korea. The fishing effort of the remaining countries (Taiwan, Poland, West Germany, Portugal, and Mexico) was small by comparison and amounted to <5% of the total effort. Mexico no longer participates in the fishery after fishing only one short season in 1979.

MAGNITUDE OF CATCHES

Yellowfin sole in the eastern Bering Sea was the species that stimulated the development of Japanese and Soviet fisheries in 1954 and 1959, respectively. Catches of yellowfin sole peaked at 610,000 MT in 1961 and declined thereafter, due to overfishing (Bakkala et al. 1979). Total groundfish catches off Alaska, consisting mainly of yellowfin sole, peaked at about 680,000 MT during 1954-63 (Table 1, Fig. 6). More than 95% of the catches came from the eastern Bering Sea during this period.

As yellowfin sole declined in abundance, the fisheries began to target on Pacific ocean perch in the Aleutians, on the eastern Bering Sea, the continental slope, and the Gulf of Alaska. Catches increased from 1963 to 1966, but the resource was not large and was soon depleted. As the fishery for Pacific ocean perch shifted to the Gulf of Alaska during this period, the eastern Bering Sea component of the total catch off Alaska dropped to about 55-65%.

Table 1.--Total groundfish catches off Alaska and distribution between the Bering Sea-Aleutians region and Gulf of Alaska, 1960-83.

Year	Total catch (1,000 MT)	Percent distribution	
		Bering Sea-Aleutians	Gulf of Alaska
1954	13	100.0	0
1955	15	100.0	0
1956	25	99.4	0.6
1957	24	99.7	0.3
1958	51	99.9	0.1
1959	222	99.9	0.1
1960	538	99.9	0.1
1961	682	99.9	0.1
1962	607	99.9	0.1
1963	331	96.8	3.2
1964	759	67.3	32.7
1965	858	54.2	45.8
1966	684	75.4	24.6
1967	1,066	86.8	13.2
1968	1,202	88.0	12.0
1969	1,372	91.5	8.5
1970	1,804	94.7	5.3
1971	2,311	94.7	5.3
1972	2,515	92.8	7.2
1973	2,280	92.2	7.8
1974	2,180	91.2	8.8
1975	1,830	89.8	10.2
1976	1,752	90.3	9.7
1977	1,458	86.2	13.9
1978	1,573	89.3	10.7
1979	1,444	88.0	12.0
1980	1,585	86.0	14.0
1981	1,718	85.0	15.0
1982	1,697	86.0	14.0
1983	1,929	84.0	16.0

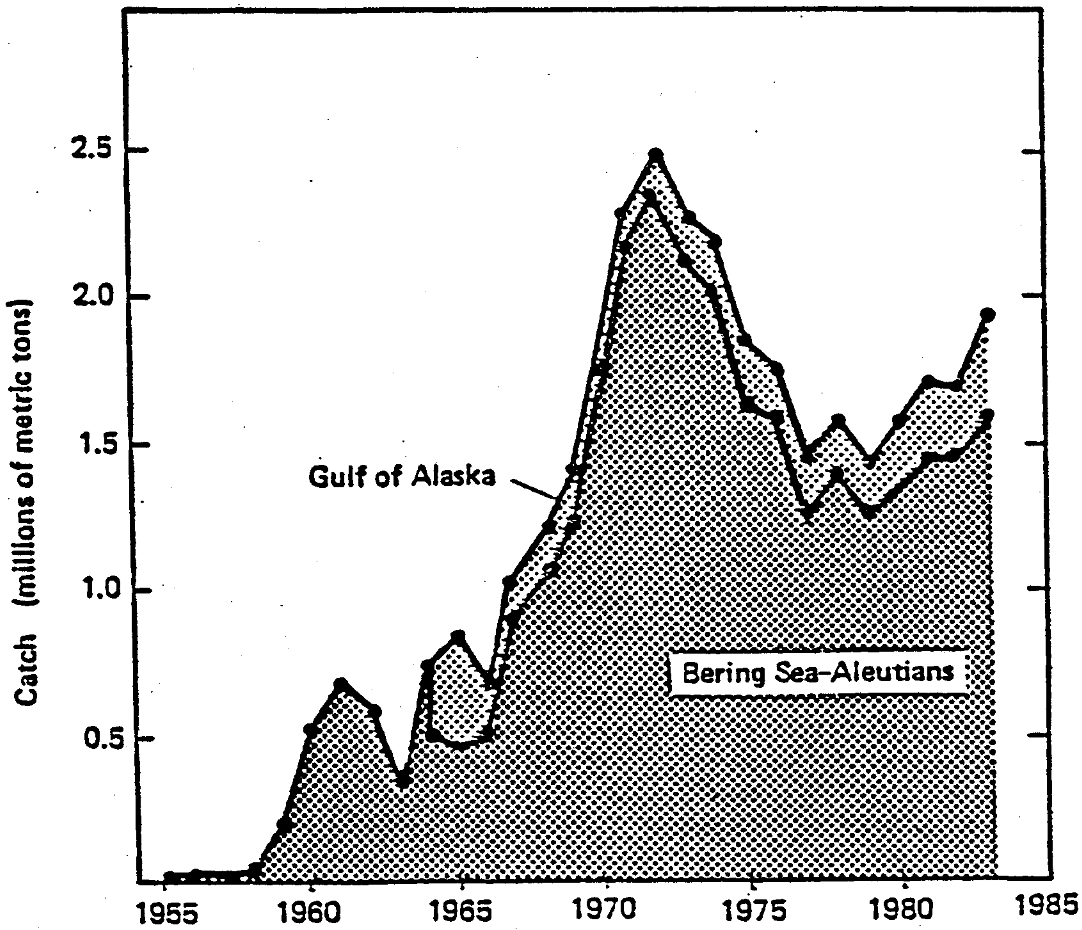

Figure 6.--Historical catches of groundfish off Alaska, 1954-83.

The groundfish catch increased dramatically again after the fisheries shifted to pollock as a target species beginning in 1964. The utilization of the abundant pollock resource became possible with the introduction of automated "surimi" (minced meat) operations aboard large fishing and mother ship vessels. Total groundfish catches peaked at 2.5 million MT 1972 and during the period from 1966 to 1977 pollock generally accounted for over 85% of the total catch. Since most of the pollock resource is concentrated in the eastern Bering Sea, the Bering Sea-Aleutians component of the catch gradually increased to over 85% of the catch off Alaska (Fig. 6).

In 1977, the Magnuson Act was implemented and catch levels became regulated. Catches were reduced from 1.8 million MT in 1976 to 1.5 million MT in 1977 as all the foreign fishing activities came under a common set of U.S. fishing regulations. Catches, however, increased again as conditions of groundfish resources in later years improved (Bakkala and Low 1984). In 1983, 1.6 million MT of groundfish were landed by the foreign and joint venture fishery.

VESSELS AND TRAWL GEAR

The trawl fisheries off Alaska use several types of vessels which can be divided into two main modes of operation: 1) mother ship fleet operations in which several small fishing boats deliver their catches to a mother ship for processing and 2) the independent trawler operations in which trawlers catch, process, and freeze their own catch. Functional descriptions of these vessels are given in Table 2 and their physical characteristics in Table 3. Comparative sizes of typical foreign and domestic vessels are illustrated in Figure 7. General descriptions of the vessels are provided by Chitwood (1969), Bakkala et al. (1979), and Nelson et al. (1981).

The mother ship fleets are composed of varying numbers of catcher boats (pair trawlers, Danish seiners, and stern trawlers); the size of an individual fleet is dependent upon the processing capacity of the mother ship. The catcher boats deliver their catches in detachable cod ends to the mother ship for processing. Small motor boats called "kawasaki" normally deliver the full cod ends to Japanese mother ships and return empty cod ends to the catcher boats. Recent U.S. joint venture operations, in which U.S. trawlers catch and deliver cod ends to foreign processor vessels, is another form of the mother ship fishery. The U.S. observers monitoring these joint venture operations have noted that cod ends full of fish have been lost during the transfer to the mother ship.

Typically, a Japanese mother ship is 175-m long and employs 6-20 catcher vessels varying in length from 27 to 51 m. Most of the mother ships are in excess of 10,000 gross registered tons (GRT), and the catcher boats from 200 to 500 GRT. The independent trawlers vary from the small (50 m, 350 GRT) class to the large catcher processors (110 m, 5,500 GRT).

Four fishing techniques have been employed in the groundfish fishery: pair trawling, Danish seining, side trawling, and stern trawling. Pair trawling is the primary technique employed by the catcher boats of the Japanese mother ship fleets. Unlike the other fishing gear which is towed by a single vessel, a pair trawl is towed between two boats moving along parallel course. The Danish seining differs from trawling in that the net is laid out along the bottom with wings spread. It is then towed slowly, causing the wings to close which drives the fish into the belly of the net. The gear is mainly employed by the Japanese mother ship fishery for highly concentrated fish such as yellowfin sole and pollock. Its use, however, has been reduced in recent years in favor of pair trawls. Japan utilizes all four techniques of fishing and fisheries of all other nations utilize stern trawls.

The size and dimensions of fishing gear utilized off Alaska depends on the size of the catcher boat. These characteristics are summarized in Table 4.

Cod end mesh sizes have been measured by U.S. observers, whereas the average area of netting material per trawl was derived from calculations of the net dimensions. The cod end mesh sizes vary from 8.0 to 13.0 cm, and the amount of netting material per trawl from 1,400 to 4,900 m^2 (Table 4).

FISHING EFFORT

An index of fishing effort, as it relates to the potential amount of trawl gear that could be lost or discarded and be a potential source of entanglement to marine mammals, is the number of vessel-months of trawl

Table 2.--Type of vessel utilized in the groundfish fishery off Alaska (GRT = gross registered ton).

Vessel class	Definition
Mother ship fleets	
Mother ship - surimi	Mother ship fleets with capacity to produce surimi (a minced fish product), frozen products, and meal.
Mother ship - freezer	Mother ship fleets with capacity to produce frozen products and meal.
Mother ship - joint venture	Mother ship fleets where the catcher boat fleet is composed of U.S. trawlers and the mother ship is of foreign registry. Fish caught are defined as U.S. landings.
Catcher boats Pair trawler Danish seiner Side trawler Dependent stern trawler	Fleet of 6 to 20 vessels which transfer catch to mother ship for processing. In the foreign directed fishery, side trawlers have been phased out and the numbers of Danish seiners and stern trawlers have been reduced. Pair trawlers predominate in the present Japanese fleets. In the growing joint venture fishery, the catcher boats are U.S. small stern trawlers.
Independent trawlers	
Large side trawler	Has been replaced by more efficient stern trawlers. May transfer catch to mother ships but could operate independently and process and freeze own catch. Soviet vessel abbreviation - SRTM.
Small stern trawler	Independent stern trawler <1,500 GRT. Processes and freezes own catch.
Large freezer trawler	Independent stern trawler 1,500 GRT or greater with capacity to produce frozen products and meal.
Large surimi trawler	Independent stern trawler 1,500 GRT or greater with capacity to produce surimi, frozen products, and meal.

Table 3.--Physical characteristics of foreign vessels in the Bering Sea-Aleutians and North Pacific groundfish fishery.

Nation	Vessel class	Gross tons	Length (m)	Horsepower	No. in crew
Japan	Mother ship (Surimi, freezer, and joint venture)	6,318-27,060	135-201	9,100	250-270
	Catcher boats				
	Pair trawler	125-215	32-38	--	12
	Danish seiner	97-150	27-38	--	18
	Small stern trawler	279-280	51-58	--	--
	Small stern trawler	350-500	50-60	1,200-2,700	22-32
	Large freezer trawler	2,000-4,000	75-102	3,400-4,400	45-60
	Large surimi trawler	2,700-7,500	92-143	3,400-5,000	60-100
U.S.S.R.	Mother ship (Freezer and joint venture)	4,000-18,000	110-174	2,000-5,000	<280
	Catcher boats				
	Small side trawler	265-335	38	300-400	22-26
	Medium side trawler	505-630	52	540-650	26-28
	Large side trawler (SRTM)	700	54	800	30
	Small stern trawler (SRTK)	775	55	1,000	--
	Large freezer trawler (BMRT)	2,300-3,800	76-89	1,900-2,000	87-96
	Large freezer trawler (RTM)	2,100-2,200	82-83	2,320	78-80
Republic of Korea	Mother ship (Joint venture)	8,506-23,799	52-74	--	--
	Small stern trawler	404-1,438	51-70	--	--
	Large stern trawler	2,000-4,000	75-102	3,400-4,400	45-60
Taiwan	Small stern trawler	620-904	52-55	--	--

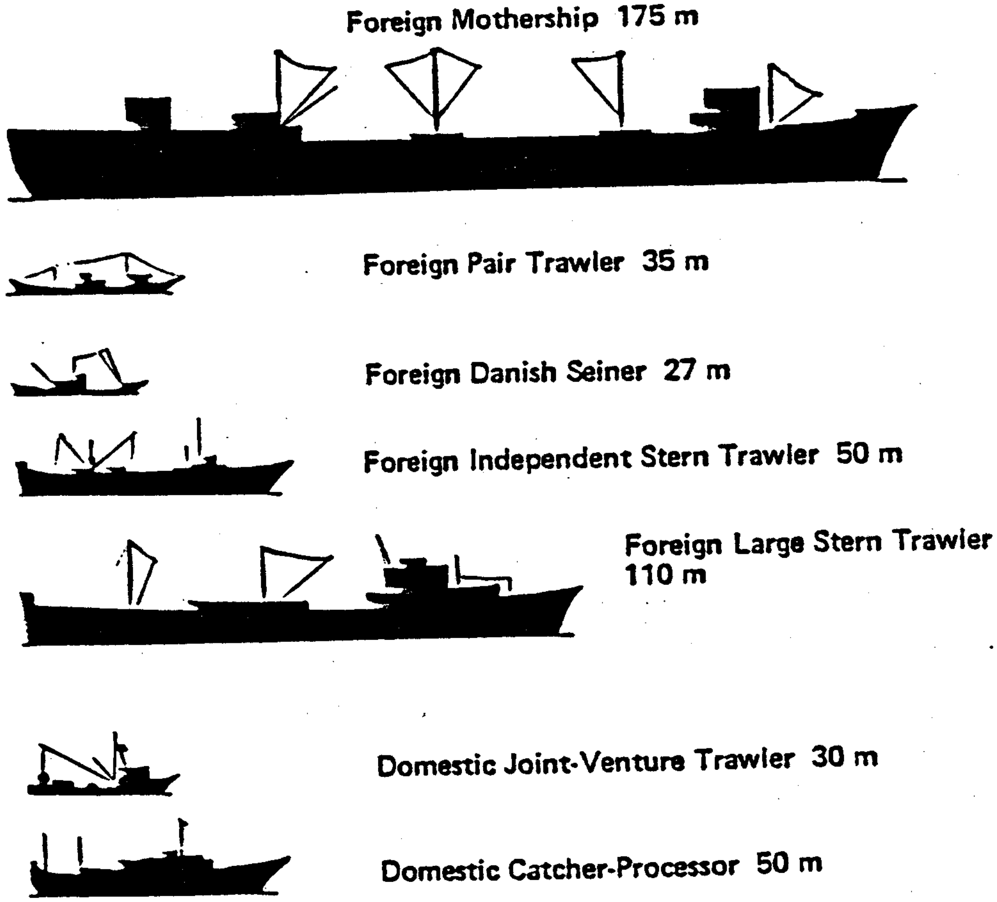

Figure 7.--Typical size of vessels employed in the trawl fisheries off Alaska.

Table 4.--Typical dimensions of trawl gear utilized off Alaska.

	Vertical opening (m)	Horizontal opening (m)	Headrope length (m)	Footrope length (m)	Cod end mesh (cm)	Area of netting material (m^2)
Japanese						
Dependent stern trawlers	4-9	24-30	36-54	8.0-8.5	8.0-8.5	2,100
Pair trawlers	7.5	56	130	148	8.0-9.0	4,150
Danish seiners	7	35	115	128	7.5-9.0	2,300
Large independent stern trawlers	7-27	22-35	50-85	54-90	9.0-13.0	4,900
Small independent stern trawlers	3.5-7.5	12-30	55-65	50-70	8.0-13.0	2,100
Soviet						
Bottom trawl	4.5-8	16-28	31-50	35-60	8.0-13.0	1,400
Pelagic trawl	25-30	35-45	70-120	70-120	8.0-13.0	4,900
Korean trawl	6-7.5	22-40	64-80	75-100	8.0-13.0	2,900
Polish trawl	18-23	20-68	55-112	55-112	8.0-13.0	2,900

operations. This effort unit can then be extrapolated to the number of trawl drags and the amount of netting material fished. Fishing effort also provides some indication of the amount of discarded fishing associated debris such as plastic banding material and fragments of netting. Fur seals have been noted to become entangled in these smaller pieces of debris (Fiscus and Kozloff 1972).

Number of Fishing Vessels

Drawing upon information provided by Chitwood (1969), Forrester et al. (1978), and annual reports on foreign fishing activities off Alaska issued by the National Marine Fisheries Service Law Enforcement Branch in Juneau, the composite compilation of the number of trawlers (excluding support vessels) that operated off Alaska in 1933-84 is shown in Table 5 and Figure 8.

Before World War II, the number of trawlers that operated off Alaska was no more than 13. The fishery resumed after the war with 11 vessels in 1954 which increased to 82 vessels by 1959 when the U.S.S.R. joined the fishery. The fleet size built rapidly to 432 vessels by 1963. During 1964-75, the number of vessels generally varied between 300 and 400. However, in 1976, just before the implementation of the Magnuson Act, the number of vessels increased dramatically to 422--a level at or near the historical peak for the fishery. Therafter, the number of foreign trawlers gradually declined as the domestic fisheries (joint venture with foreign

Table 5.—Estimated total numbers of trawlers that operated off Alaska, 1933-84.

Year	Japan	U.S.S.R.	Republic of Korea	Poland	Taiwan	West Germany	Mexico and Spain	United States joint venture	United States catcher processor	Total
1933	5									5
1934	5									5
1935	11									11
1936	8									8
1937	13									13
1940	8									8
1941	12									12
1954	11									11
1955	9									9
1956	13									13
1957	13									13
1958	29									29
1959	62	20								82
1960	190	80								270
1961	200	100								300
1962	200	150								350
1963	221	211								432
1964	150	196								346
1965	131	201								332
1966	166	240								406
1967	166	174								340
1968	157	115								272
1969	175	137								312
1970	221	175								396
1971	207	174								381
1972	218	158								376
1973	212	107								319
1974	211	126	15	1						353
1975	206	65	13	3	1					288
1976	237	[1]27	57	—	1					422
1977	288	35	18	2	1					344
1978	218	48	13	2	5					286
1979	210	41	17	13	3		3	3		284
1980	213	40	23	24	4	1	0	22	1	328
1981	210	6	31	25	3	1	0	36	1	313
1982	203	7	31	3	4	1	0	53	2	304
1983	205	8	29	—	3	1	0	65	6	317
1984[1]	185	7	28	4	3	1	1	85	8	322

[1]Preliminary estimates.

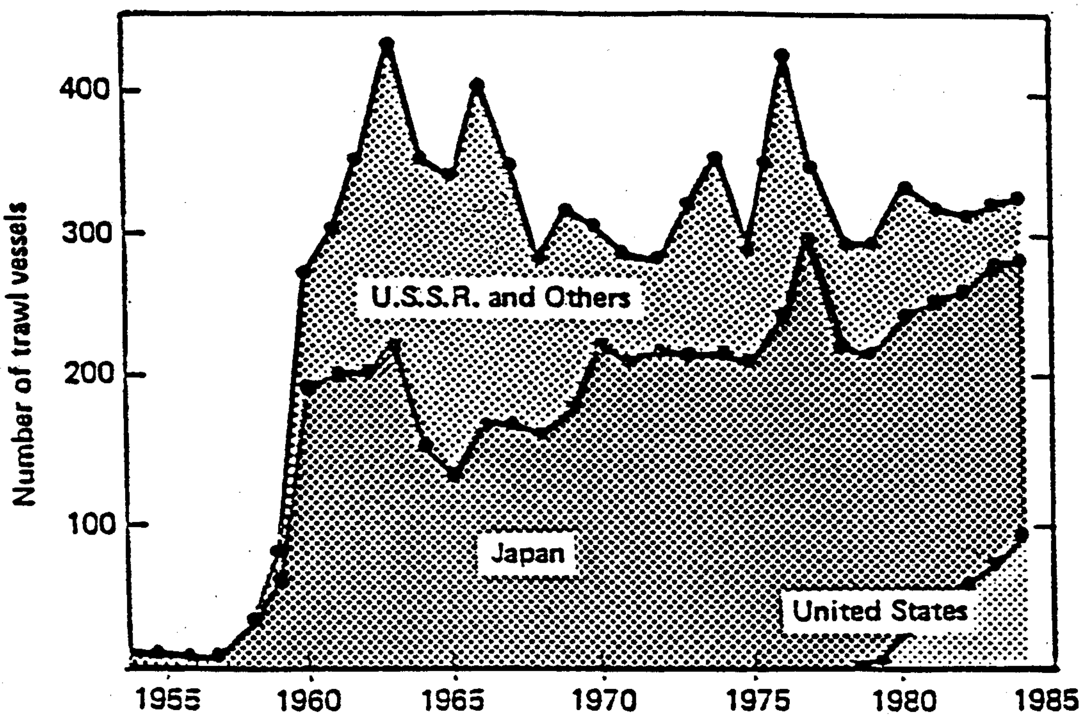

Figure 8.--Total number of trawlers that operated off Alaska, 1954-84.

vessels and purely domestic operations) became established and regulations became more restrictive on the foreign fisheries. In addition, the U.S.S.R. and Poland were denied direct fishing privileges during 1980-83 which resulted in further considerable reduction in the number of foreign vessels that operated off Alaska. By 1984, the number of foreign trawlers had been reduced to 229; however, the total number of vessels still exceeded 300 (322) considering the 93 U.S. trawlers.

Vessel-Months of Trawling

Before 1963, the vessel-months of effort were estimated by multiplying the number of vessels (sighted or reported) by typical days of operation per year. The typical number of days of operation and average number of drags per day were derived from data collected by the U.S. Foreign Fisheries Observer Program (Table 6). From 1964 to 1976, the number of vessel-months of operation was estimated from monthly sightings and reports of foreign vessel operations as given in "Foreign fishing activities in the Bering Sea and Gulf of Alaska" issued by the NMFS Law Enforcement Branch at Juneau, Alaska. The vessels that were on the grounds each month were assumed to have operated the whole month, even though the actual number of days of operation would vary depending on weather conditions and other factors. This method of calculation results in a maximum estimate of fishing effort. After 1976, the actual number of foreign fishing days off Alaska were provided by radio reports from the vessels under regulations promulgated by the Magnuson Act. The number of vessel-months of operation can be tallied from these reports. However, to maintain comparable estimates of fishing effort, the same procedure of estimation for 1964-76 was used for the 1977-83 period.

Table 6.--Typical number of vessel days of operation per year and average number of trawl drags per day for trawl vessels that operated off Alaska.

Country	Trawl vessels	Vessel-days of operation per year	Number of drags per day
Japan	Mother ship catcher boats	150	4
	Large trawler	220	5
	Small trawler	220	4
	Joint venture trawler	70	0
U.S.S.R.	Trawler	180	3
	Joint venture trawler	70	0
Republic of Korea	Trawler	200	5
	Joint venture trawler	130	0
Poland	Trawler	70	3
	Joint venture trawler	40	0
Taiwan	Trawler	100	3
	Joint-venture trawler	40	0
West Germany	Trawler	200	3
	Joint-venture trawler	80	0
Mexico	Trawler	180	3

Table 7 shows the estimated amount of trawl fishing effort off Alaska from 1954 to 83 by nation and geographical region. These data are also plotted in Figure 9. The total amount of fishing effort increased rapidly from 66 vessel-months of trawl operations in 1954 to 2,700 vessel-months in 1963. The effort declined to an average of about 2,200 vessel-months during the 12 years (1964-75). In 1976, the effort increased dramatically to a historical peak of 3,215 vessel-months. However, after the Magnuson Act was implemented a year later, the effort declined gradually to the level in the late 1960's.

Despite recent expansions in the domestic fisheries after 1980, the effort is still predominantly foreign. Japan has remained the nation with the largest fishing effort. Fishing effort by the U.S.S.R. was actually as high or higher than that of Japan during 1961-67, but declined after 1967 and in 1980 direct fishing operations ceased due to U.S. regulations. Fishing effort by the other countries is still a small percentage of the total.

Most of the fishing effort was concentrated in the Bering Sea-Aleutian region (Fig. 9). At the inception of the trawl fishery in the Gulf of Alaska when the fisheries targeted on Pacific ocean perch, fishing effort was relatively high. When this resource was depleted after 1967, the fishing effort decreased dramatically in the Gulf of Alaska and remained at a relatively constant level (11%) of the total fishing effort.

Although the trawl fishery is a year-round operation, most of the effort is concentrated during the warmer summer months. Typically, vessel-months of effort are distributed as follows:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Percent	3.6	5.9	6.0	4.8	7.2	16.8	16.9	10.1	10.3	8.3	6.0	3.9

Table 7.--Estimated amount of trawl fishing effort off Alaska expressed in number of vessel-months of operation, 1954-83.

	Effort in vessel-months by nation				Effort by region	
Year	Japan	U.S.S.R.	Others	Total	Bering Sea-Aleutians	Gulf of Alaska
1954	66			66		
1955	54			54		
1956	78			78		
1957	78			78		
1958	174			174		
1959	350	50		400		
1960	1,400	300		1,700		
1961	1,100	900		2,000		
1962	1,100	900		2,000	1,600	400
1963	1,100	1,600		2,700	1,700	1,000
1964	760	1,360		2,120	1,220	900
1965	740	1,860		2,600	1,600	1,000
1966	875	1,180		2,055	1,093	962
1967	1,015	935		1,950	1,445	505
1968	1,275	675	5	1,955	1,728	227
1969	1,220	695	5	1,920	1,759	161
1970	1,560	835	5	2,400	2,176	224
1971	1,580	960	5	2,545	2,340	205
1972	1,555	790	10	2,355	2,102	253
1973	1,445	705	10	2,160	1,890	270
1974	1,565	770	25	2,360	2,114	246
1975	1,180	680	50	1,910	1,660	250
1976	1,935	1,000	280	3,215	2,965	250
1977	1,826	416	67	2,309	2,136	250
1978	1,832	363	122	2,317	2,078	239
1979	1,776	310	355	2,391	2,175	266
1980	1,860	141	390	2,391	2,029	337
1981	1,365	0	520	1,885	1,635	250
1982	1,356	0	420	1,776	1,571	205
1983	1,704	0	410	2,114	1,726	388

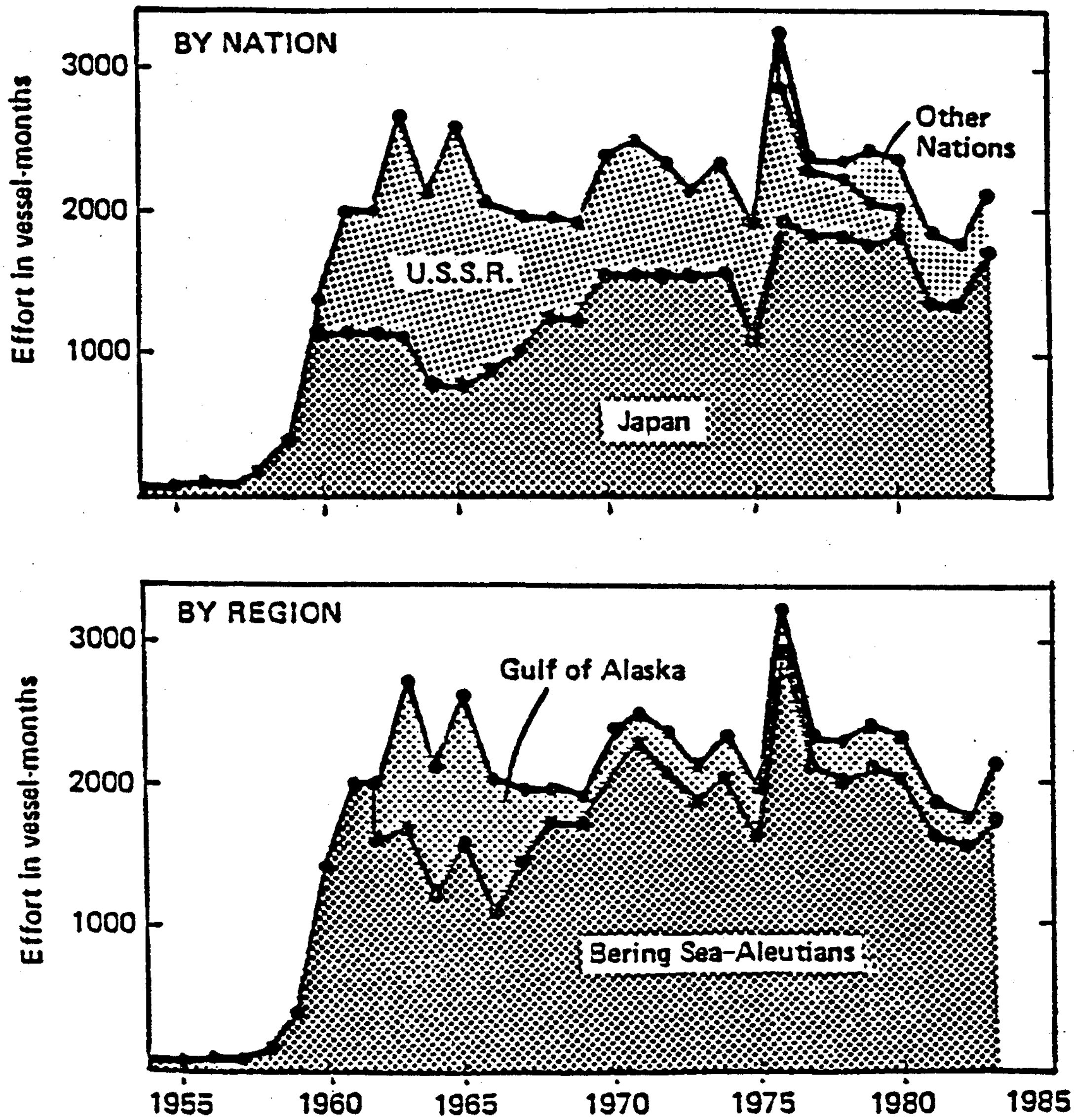

Figure 9.--Total fishing effort off Alaska, by nation (top panel) and by region (bottom panel), 1954-83.

Observations on Net Loss in 1983

The Magnuson Act requires that foreign vessels fishing in the U.S. 200-mile fishery conservation zone (FCZ) carry U.S. fisheries observers. Foreign vessels participating in joint ventures with U.S. catcher boats in federally managed waters in the FCZ (3-200 miles) are also subject to this requirement. The Magnuson Act authorizes the use of observers for the purposes of 1) collecting biological data needed for fisheries management, 2) monitoring compliance to fishing regulations, and 3) cooperating in research related to the conservation of living marine resources. The Northwest and Alaska Fisheries Center administers the observer program for foreign and joint venture fisheries in the U.S. FCZ in the eastern Bering Sea and northeast Pacific Ocean. This program has been used to provide data on a wide range of management, compliance, and research problems (French et al. 1982).

One of the areas in which the program has been involved is the collection of data on the number and type of marine mammals incidentally caught during fishing operations. Based on data collected by observers, Loughlin et al. (1983) reported on the number and type of animals caught by the trawl fishery from 1978 through 1981. In addition to this active interaction between marine mammals and the trawl fishery, Fiscus and Kozloff (1972) and Fowler (1982) have reported on a second type of interaction resulting in the entanglement of animals in trawl netting discarded or lost from trawl vessels.

In response to Fowler's report, the observer program instructed its observers to monitor the discarding and loss of trawl netting material in the foreign and joint venture fisheries. The purpose of the project was not necessarily to provide a quantitative measure of the amount of netting lost or discarded annually but to determine the type of information that could be collected by observers. A more detailed study would be developed and implemented at a later time if it was found that it was feasible for observers to collect data which could be used to quantitatively measure the type and amount of netting lost and discarded in the fishery.

In this initial study, observers were asked to monitor net-mending operations to determine how often nets were repaired and the number and size of pieces of webbing that were discarded during such occasions. They were also asked to determine the fate of any cod ends that were damaged beyond repair and to report on the loss of nets during trawling or in delivery to a mother ship or joint venture operation. The project was begun in the fall of 1982 and continued during 1983 and 1984. This report provides a summary of some of the information collected during 1983, the only complete year of data collection at this time.

During 1983, U.S. fisheries observers were stationed aboard foreign vessels in the Bering Sea-Aleutian region for 13,994 days which accounted for 44.2% of the total foreign effort. In the Gulf of Alaska region, observers spent 4,046 days aboard foreign vessels accounting for 50.6% of the total effort. There were 368 reports summarizing data collected on the discard and loss of netting in the Bering Sea-Aleutian region and 92 reports from the Gulf of Alaska region. From review of these reports, it is apparent that many observers had difficulties monitoring net-mending operations and thus collecting data on the number and size of materials discarded. Observers found that net-mending operations were usually performed during the period observers were busy performing sampling duties below deck. It was also noted that it was difficult to monitor net-mending activities without vessel personnel being aware of the observer's activity and purpose. Debris from net-mending activities would likely not be tossed overboard in the observer's presence. For these reasons, the information reported by observers which was found most useful for this report was the number of instances where nets or cod ends were accidentally lost during fishing operations.

In the Bering Sea-Aleutian region, 17 of the 368 reports submitted by observers indicated that a net or large portion of the net was lost during a fishing operation (Table 8). Of the 17 reports, 8 were from vessels participating directly in the foreign fishery. The eight reports cited the loss of eight nets or portions of nets. If it is assumed that these

Table 8.--Number of reports for U.S. observers of losses of nets or portions of nets and estimated number of losses in the entire foreign and joint venture groundfish fishery in the Bering Sea-Aleutian region and the Gulf of Alaska region in 1983.

Region/nation/vessel class	Total No. of reports	No. of reports with net loss	No. of reported lost nets	Percent observer coverage	Estimated No. of net losses[1]
Bering Sea-Aleutian					
Japan					
Mother ship	7	1	1	86.7	1
Large trawlers	29	1	1	71.8	1
Small trawlers	250	4	4	36.4	11
South Korea-trawlers	60	1	1	45.7	2
West Germany-trawlers	3	1	1	70.1	1
Total foreign fishery	349	8	8	43.5	16
Joint venture	19	9	15	56.6	26
Total all fisheries	368	17	23	44.2	42
Gulf of Alaska					
Japan					
Large trawlers	15	1	1	66.6	2
Small trawlers	30	1	1	57.1	2
South Korea	29	0	0	38.5	0
Total foreign fisheries	74	2	2	41.3	4
Joint venture	18	10	14	72.9	19
Total all fisheries	92	12	16	50.6	23

[1]Number of net losses determined by: Total number = Number of reported lost nets/percent observer coverage.

reports account for all of the number of nets lost during the period of observer sampling, then an estimate of the number of nets possibly lost during the 1983 fishery can be extrapolated to vessels without observers (total number of net losses equal number of reported net losses/percentage observer coverage). The resultant estimated number of nets or large portion of nets lost in the foreign fishery in 1983 was 16 (Table 8). The other nine reports were from the joint venture fishery. They listed 16 instances where cod ends were lost in the transfer of either full or empty cod ends between foreign processing vessels and U.S. catcher boats. The estimated number of cod ends lost in the entire joint venture fishery in the Bering Sea-Aleutian region in 1983 was 26 (Table 8). There were two reports from observers indicating the loss of two nets or portions of the nets in the foreign fishery in the Gulf of Alaska in 1983. These two reports result in an estimated loss of four nets or portions of nets in 1983 (Table 8). Observers reported 14 cod ends lost during transfers in joint venture fisheries in the Gulf of Alaska resulting in an estimated loss of 19 cod ends in the joint venture fishery (Table 8).

Therefore, a total of 65 nets or portions of nets were estimated to have been lost in the foreign and joint venture fisheries off Alaska in 1983. Most of the estimated losses (45) occurred in the process of transferring cod ends between processing vessels and catcher boats in joint-venture fisheries. It should be clearly noted that this estimate does not provide a measure of the amount of net material associated with these losses but only an indication as to the number of net losses which may have occurred in the 1983 trawl fishery.

EXTRAPOLATED ESTIMATE OF NET LOSS 1954-82

To provide the workshop a starting point from which to discuss the potential net loss associated historically with the trawl fishery, we have made an estimate of the net loss in the trawl fishery for 1954-82. There are no direct observations on the number of nets damaged or lost in the trawl fisheries other than from U.S. observers in 1983. If the assumption is made that the rate of loss for all years was the same as that observed in 1983, then it is possible to estimate the loss for earlier years. The 1983 data suggest that the rate of loss in the foreign fishery is distinctively different from that of the joint venture fishery. There are two possible sources of losses in the joint venture fishery: loss associated directly with trawling operations and the additional loss due to the at-sea transfer of cod ends. Therefore, in estimating net losses for years preceding 1983, two rates (number of nets or large portions lost per vessel-month) of loss were applied to the effort (vessel-months) from earlier years (Table 9).

It is difficult to determine how realistic the estimates of net loss are for 1954-82 because there is no corroborative information available. We have surmised that the estimates for 1977-82 may be good since the changes in gear used, target species sought, and grounds fished by the foreign fishery have been minor. We suspect that the gear loss in the Gulf of Alaska from 1965 to 1977 may have been higher than estimated since foreign vessels targeted on rockfish in areas in the eastern Gulf of Alaska over rather rough bottom. The likelihood of gear loss or damage would be increased in that type of fishery. We also suspect that for the period 1960-64, the amount of gear lost may have been substantially higher than estimated, since substantial foreign fisheries targeted on Pacific ocean perch over rather rough sea bottoms at that time. Before 1960, the fishery was to some extent still experimental; therefore, the probability of gear damage and loss may have been higher than estimated as well.

DISCUSSION

It is evident to us that there is no reliable estimate of the amount of trawl gear damaged or lost in the trawl fishery off Alaska. Although actual observations were made by U.S. observers in 1983, they may be

Table 9.--Extrapolated estimate of net or large portions of net loss in the trawl fisheries off Alaska, 1954-83.

Year	Bering Sea-Aleutians	Gulf of Alaska	Total
1954	1	0	1
1955	1	0	1
1956	1	0	1
1957	1	0	1
1958	2	0	2
1959	4	0	4
1960	10	4	14
1961	16	4	20
1962	16	4	20
1963	17	10	27
1964	12	9	21
1965	16	10	26
1966	11	10	21
1967	14	5	19
1968	17	3	20
1969	17	2	19
1970	22	3	25
1971	23	2	25
1972	21	3	24
1973	18	3	21
1974	21	3	24
1975	17	3	20
1976	29	3	32
1977	21	3	24
1978	21	3	24
1979	22	5	27
1980	20	15	35
1981	27	22	49
1982	34	22	56
1983	42	23	65

inadequate because of sampling circumstances. Rates of gear loss before 1977 are even less reliable because levels of fishing effort can only be approximated. The potential for obtaining future data which will provide more reliable estimates of the amount of gear lost now exists through the observer program. By law, all foreign vessels must now carry U.S. fisheries observers while participating in directed or joint venture fishing activities in the U.S. FCZ. There is a need to evaluate the work already performed by observers in this area and develop a plan for future data collections which will provide the information needed to measure the impact of the trawl fishery. Many foreign vessel operators seem to be acutely aware of the interest of observers in the collection of data on net loss and the discard of debris. It is apparent that the presence and activities of observers can also be used as a deterrent to the discard of debris by foreign vesssels.

As we improve our sampling of the foreign and joint venture operations, however, we need to obtain equivalent data from the rapidly developing domestic trawl fisheries. The expansion of the domestic fleet has essentially limited foreign fisheries to targeting on pollock, yellowfin sole, and turbot in the eastern Bering Sea, and pollock in the Gulf of Alaska. Fisheries targeting on pollock and yellowfin sole operate over relatively smooth ocean bottoms or use midwater trawl gear. As such, the probability of gear damage and loss in these fisheries is low.

On the other hand, domestic fisheries have developed for Pacific ocean perch and Atka mackerel in the Aleutians and flatfishes and other bottom species in the Gulf of Alaska. These fisheries are often conducted over hard uncertain bottom where the probability of gear loss is higher. The need to monitor gear damage and loss in these fisheries may be greater than in other domestic fisheries that target on pollock, yellowfin sole, and Pacific cod over relatively smooth ocean bottom.

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THE OREGON EXPERIENCE

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ABSTRACT

There is virtually no information available to the Oregon Department of Fish and Wildlife to judge the extent of injury or death to fish, aquatic, and terrestrial wildlife resulting from ingestion of or entanglement in plastic debris. This paper describes the impacts of plastic debris on fish and wildlife along the 563 km (350-mi) Oregon coast based on the findings of a cleanup project.

To learn more about the presence of plastic debris on the Oregon coast, the department conducted a coastwide volunteer effort to pick up plastic on 13 October 1984. More than 2,000 individuals volunteered to collect and inventory the debris. By filling out questionnaires, they indicated pounds collected, miles walked, and whether debris was generated by beach use or ocean drift. Debris categories included food packaging and utensils, fishing gear, rope, strapping, six-pack holders, bottles and jugs, or bags and sheeting. Dead birds found on the beach this fall will be sent to the Oregon Marine Science Center for necropsy to check for plastic particles.

I am pleased to attend this workshop and share a unique experience I had during the past 5 months. It all began because the May-June issue of the Alaska Fish and Game Department's magazine was delivered to my office by mistake. Flipping through it, I was drawn to an article entitled, "The plague of plastics," by freelance writer, Tom Paul. He wrote about the increasing proliferation of plastic debris into the natural environment and the resulting ingestion or entanglement by wildlife.

Although I have no scientific background, I was aware birds become entangled in monofilament fishing line and six-pack rings, but I didn't know they had an appetite for styrofoam and small bits of plastic.

In July, I attended the annual meeting of the Western Association of Fish and Wildlife agencies. This gave me the opportunity to talk to fish and wildlife managers from the 14 western states, Alberta, and British Columbia. The folks I talked to agreed they had a vague awareness there was a problem with plastic but had not seen much written about it.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

At the end of the conference, the Western Association adopted a resolution asking its members to "inform legislative and administrative bodies and the general public of the danger of plastic debris to wildlife, and of the need to reduce its proliferation into the environment."

I had the idea of organizing a cleanup of plastic debris on Oregon's 563 km (350 mi) of coast. All but 42 km (26 mi) is publicly owned.

A steering committee was formed. We divided the coast into 14 zones and found local residents to be "zone captains" to identify which areas were accessible and where debris, once collected, could be stacked.

Our statewide newspaper, The Oregonian, published an article on 17 August explaining the project and my telephone has never stopped ringing. We had groups and individuals volunteer to help clean up debris, Chambers of Commerce and service clubs offer to feed volunteers, five coastal community banks contribute money for food, and food brokers donate 307 dozen hot dogs and buns to feed the volunteers. A public utility company provided 2,000 reprints of a Parks Magazine article entitled, "Plastic pollution: A worldwide oceanic problem," and these were mailed to each volunteer. A discount store chain printed 5,000 large posters asking marine users to keep plastic on board. The Oregon Sanitary Service Institute volunteered trucks and drivers and paid the landfill fees. They also provided special T-shirts for zone captains, steering committee members, and refuse collectors.

My original goal was 1,500 volunteers--roughly 10 for each of the 241 km (150 mi) of accessible beach. We picked Saturday, 13 October, to coincide with the Year of the Ocean and Coastweek activities. The pickup hours of 9 a.m. to 12 p.m. agreed with favorable tides.

The news media loved the idea from the beginning. Stories about the cleanup appeared statewide on a regular basis, raising the public's awareness about plastic debris and its impact on wildlife, and outlining how people with no special equipment or training could be personally involved.

On Friday, 12 October, the weather took a drastic turn for the worse. Gale force winds lashed the coast. Small craft and beach erosion warnings were repeated over and over on the radio and people were cautioned to stay off the north coast beaches.

Saturday morning dawned to more high wind, hail, and driving rain. Despite the black sky and bleak forecast, volunteers arrived by the car and busload, dressed for the weather and raring to go. Because emergency services closed two zones, some volunteers worked in the dune grass and along beach roads and parking areas.

At the designated meeting sites, each volunteer was given a 5.3-liter (20-gal) plastic collection sack, a free lunch ticket, a verbal warning about sneaker waves, and a questionnaire.

The questionnaire asked how many people were in the party, the number of males and females, and the range of age. It asked for the location and number of miles gleaned and whether it was sandy beach, estuary, rocky beach, or road access.

The questionnaire listed different types of plastic debris and had a category for special observations. They were on 12.7 x 17.8 cm (5 x 7 in.) card stock and included my name and return address for easy mailing.

In addition to listing plastic debris, volunteers were asked to note dead or sick sea lions or seals because of an outbreak of leptospirosis in marine mammals. Fresh dead birds were delivered to the Hatfield Marine Science Center Disease Laboratory for the Oregon State University staff to necropsy. Twenty-one birds were delivered to the center.

On Monday after the cleanup, I telephoned the zone captains to obtain an estimate of the number of volunteers participating and the sacks collected. A total of 2,100 volunteers in the 14 zones filled 2,412, 5.3-liter (20-gal) sacks. Over half of those who participated came from inland cities and drove at least 121 km (75 mi). There was excellent involvement by coastal residents as well.

To my amazement, over 1,600 questionnaires were filled out and returned. In addition to interesting reading, the cards have given us a data base of ocean debris. We know that on 13 October 1984, the Oregon coastal beaches produced: 48,898 chunks of styrofoam larger than a baseball. Most was found adjacent to our largest river mouths, especially those with marinas or houseboat moorages upstream. Styrofoam shows up on the Oregon coast from small bead size up to pieces as large as 0.9 x 1.2 m (3 x 4 ft). Coastwide, the average percentage of styrofoam was 60% but on the north coast, it was as high as 92%. By contrast, south coast zones had smaller amounts, except on the beaches adjacent to river mouths.

Strapping bands, of which there were 2,055, were most prevalent on open beaches. They come in all colors but are uniformly about 0.9 m (3 ft) long.

Rope is in high quantity on the entire coast; 6,117 pieces were collected. Small, 0.3-m (1-ft) lengths and tangles 0.9 to 1.5 m (3- to 5-ft) long wash ashore, wound up in globs of kelp.

There were 1,442 six-pack rings. They were most prevalent on beaches frequented by picnickers which may be due to Oregon's law requiring their breakdown within 120 days when exposed to ultraviolet light.

The 4,787 plastic milk jugs, bleach bottles, shampoo, and detergent bottles were collected. Many had foreign labels and appeared to have been afloat for a long time.

Most fishing nets were found at the mouth of the Columbia River. The 1,097 pieces of fishing gear--artificial worms, large and small sections of net, or lengths of monofilament line with hooks were collected. One large net which had been on the beach for several months, weighed over 136 kg (300 lb). Fifteen to 20 units of heavy cord and fiber trawl net in 9.1-12.2 m (30-40 ft) lengths had to be hauled away by truck.

The 4,909 bags or sheets of plastic appeared in all locations. They were generated equally from beach and ocean users.

The 5,339 plastic food utensils, including snap-in cups, forks, spoons, or plates collected were more prevalent in picnic areas.

The birds collected included 10 northern fulmar, Fulmarus glacialis, 4 western grebe, Aechmophorus occidentalist, 3 western gull, Larus occidentalist, 3 Cassin's auklet, Ptchoramphus aleutica, and 1 common murre, Uria aalfe. Plastic particles were only found in three fulmars. One had styrofoam, another had a hard, blue plastic ballpoint pen clip, and the third had two hard, green plastic chips. The fulmar also had feathers, pine needles, and bits of fish bone. The western grebe stomachs were crammed with feathers. All birds had good fat content and did not appear to be starving. The examinations gave no indication of the cause of death except as the result of the heavy storm.

SO WHAT DID WE LEARN FROM THE OREGON EXPERIENCE?

First, there is not much information on the impact of plastic debris on Oregon's wildlife. We know styrofoam chunks, bottles, and lids are present but aren't ingested in the form we picked up.

We do know it is possible to find over 2,000 individuals willing to get up at 5 a.m., drive to the coast, and go out on a cold, wet blustery day to work for at least 3 h, stooping over to pick up 26.3 tons of plastic and other debris, and lugging them back to their car or truck. And after they do that, they enjoy getting together with others to compare what they found. They are also willing to sit down and fill out questionnaires and attach postage to mail in the cards.

We learned the north coast zones, adjacent to the Columbia River, had the highest incidence of discarded net and styrofoam. The south coast zone captains felt most of their plastic debris was from ocean drift because severe winds tend to keep the beaches free of lightweight material. Percentage use of beaches by humans was higher in areas adjacent to parking lots on the main highway, especially those frequented by people from the larger inland cities.

Plastic was not the only culprit on Oregon's beaches. Aluminum foil and food containers, aerosol cans, wine and liquor bottles, paper containers, and newsprint were mixed with the plastic debris. This was especially true on the south coast where the majority of debris was not plastic.

Debris found in driftwood piles, dune grass, and rock areas had a higher percentage of ocean drift.

Because plastic is lightweight and floats, it was the most obvious debris collected. We have no way to determine the amount of other material which has been discarded in our rivers or the ocean.

In several locations, having completely cleaned a section of beach on the morning of 13 October, volunteers returned to the same section a second time in the afternoon and again the next morning following a high tide. A 5.3-liter (20-gal) sack could be filled each time, and the ratio of rope, strapping bands, styrofoam, jugs, and fishing gear was the same. This leads to the conclusion that the majority of the debris on the Oregon coast is from ocean drift.

SO WHAT MIGHT BE DONE TO REDUCE OCEAN DEBRIS?

I have heard from sport and commercial fishermen and other marine users that there are not adequate disposal containers at dockside. It is much easier to dispose of debris into the water unseen than have the hassle of hauling it home. We need to involve port officials, refuse collectors, and the users in our discussions.

Now we all know there is a fine line between emotionalism being the motivator for cleaning up the beach and those who want to find out the facts and work toward solving the problem. A 1984 Marine Debris Bulletin article forecast that "Plastic particle pollution may provide the next battleground for seabird research and management." I prefer looking at the problem as an opportunity to find solutions.

In an effort to raise the public's awareness about plastic debris and wildlife and how they can solve the problem, we are producing a 12-min educational film entitled, "Get the drift." Funded by contributions from a variety of interests, it will be available in early January for use on television and to show at schools and before civic groups.

There is a perception by the public that plastic cannot be recycled. I am pleased to announce that the Society for the Plastics Industry has allocated $5 million to establish a Plastic Recycling Foundation and Institute to aggressively pursue methods to make it economically feasible to recycle plastic in large quantities. Although recycling does not specifically intercept the debris ingested by wildlife or which results in entanglement, it does allow individuals an opportunity to take preventive action and be personally involved. The plastic industry will also explore a way of having some items degrade more quickly when exposed to ultraviolet light.

The proposal by the U.S. Department of Commerce to add wording relative to discarding at sea in the commercial fishing regulations is a beginning. I recommend similar language become a part of all angling and marine board regulations.

As a promoter of a volunteer effort, I know the problem we are discussing struck a responsive chord with the public. Their donations to date have had a dollar value to my agency of over $20,000.

All of you are professional scientists, policymakers, or journalists. My wish is that you will put your knowledge about the fate and impact of marine debris into "street language." Rather than triggering counterproductive action such as restrictive legislation which could cripple several industries, we need to get our information out of the laboratories and into the minds of those who can help find practical solutions.

I appreciate having the opportunity to share the Oregon experience and will be happy to answer your questions.

Thank you.

FISH NETS AND OTHER PLASTIC LITTER ON ALASKA BEACHES

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ABSTRACT

Quantities of fish net fragments and other plastic litter on Alaska beaches at eight locations were determined by foot surveys from 1972 to 1984. The beach survey sites extended about 3,000 km, from Amchitka in the Aleutian Islands to southeastern Alaska and, therefore, provided a measure of accumulated litter from a large oceanic area. Limitations and advantages of beach surveys as an indicator of oceanic litter are discussed. Most litter was from foreign fisheries. Fragments of trawl web always constituted the bulk of the litter by weight. Japanese gill net floats were usually the most numerous item. Numbers of gill net fragments of each mesh size provide a clue to the fisheries from which they originate, thereby helping identify specific fisheries that are major sources of lost gill nets. There was little variation in composition of litter items on different beaches or in different years, but quantities of litter on different beaches varied greatly. Quantities on southeastern Alaska beaches were usually much less than in the western Aleutians. On Amchitka Island, where surveys extended over the decade 1972-82, litter rapidly increased during 1972-74 (from 122 to 345 kg/km of beach), but decreased 26% by 1982 to 255 kg/km. Between 1974 and 1982, there was a 37% reduction in weight of trawl web on Amchitka beaches, and the number of gill net floats declined 47%. The decrease in litter on Amchitka between 1974 and 1982 is attributed to fewer trawlers and gill-netters fishing off Alaska and shows that marine litter could be rapidly reduced if disposal of litter at sea were restricted.

INTRODUCTION

A serious pollution problem has resulted from the enormous quantities of plastic litter afloat on the oceans of the world. In 1975, it was estimated that 6.4 million metric tons (MT) of litter is annually discarded from ships (National Academy of Sciences 1975), and in Alaska waters about 1,664 MT of plastic litter is lost or discarded annually from fishing vessels (Merrell 1980). In Alaska, plastic litter--especially fish net fragments--is common, even in the most remote, uninhabited areas.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

The question is often asked: "So what? Why be concerned about marine litter?" Litter is aesthetically offensive. Ropes and nets disable vessels by entangling propellers, and sheet plastic can block cooling water intakes for engines. Lost or discarded litter, particularly net fragments, traps marine mammals, birds, and fish, resulting in their suffocation or starvation.

Annually, between 1972 and 1974 and again in 1982, I conducted systematic surveys of ten 1-km beaches of Amchitka Island which is 2,400 km west of Anchorage, Alaska (Merrell 1980, 1984). In 1984, I expanded the surveys to southeastern Alaska but did not repeat the Amchitka surveys.

I tried to answer several questions by my surveys: What kinds of litter were on the beaches? What were the sources of litter? Did the kinds and amounts of litter vary from area to area and from time to time? Lastly, could I develop simple, quantitative methods for measuring beach litter, methods that could be used by inexperienced people for comparable results from different observers, different years, and different geographic areas?

In this paper, I discuss and compare results of my surveys on Amchitka Island with those of surveys in southeastern Alaska, emphasizing litter that traps marine animals--trawl web, gill nets, and straps. I describe, in detail, the methods used and discuss their limitations.

SURVEY METHODS

The methods were the same for surveys of Amchitka Island and southeastern Alaska. All pieces of plastic litter visible from walking height were recorded; that is, any pieces larger than about 5 mm. Only a part of the litter actually present was accounted for because I did not try to uncover litter partially buried in sand, cobbles, or driftwood. To minimize variability caused by differences in efficiency of different individuals, I participated in all surveys. A complete description of the methods and equipment is in the appendix.

LITTER ON AMCHITKA ISLAND AND SOUTHEASTERN ALASKA BEACHES

With minor exceptions, the proportions of each kind of litter on Amchitka Island beaches were the same in 1982 as in 1972-74 (Table 1) (Merrell 1984). Although hundreds of kinds of plastic items were found, only 23 items were found 5 or more times in 1982. Twelve items were used in commercial fishing; most of the other items were probably discarded as garbage from fishing vessels. The amount of litter on Amchitka Island rapidly increased during 1972-74 (from 122 to 345 kg/km of beach) but decreased 35% by 1982 (to 225 kg/km of beach).

During the 4 years of surveys on Amchitka Island, trawl-web fragments were, by far, the most common item: 76-85% of all litter, by weight (Fig. 1). Trawl fishing, primarily by Japan and the U.S.S.R., on the continental shelf of Alaska reached a peak in 1972, when 706 trawlers were fishing in the area (J. C. Hammond, Law Enforcement Br., Natl. Mar. Fish Serv., NOAA, Juneau Alaska, pers. commun.). Subsequently in 1976, as a result of

Table 1.--Weight and number per kilometer of 23 most common items of plastic litter on ten 1-km beaches on Amchitka Island, 1972-74 and 1982 (asterisks indicate commercial fishing gear).

Items of plastic litter	Kilograms per kilometer				Number per kilometer			
	1972	1973	1974	1982	1972	1973	1974	1982
Trawl web*	103.87	122.15	271.75	171.27	12.3	16.7	23.7	34.0
Trawl floats*	4.70	10.09	18.25	19.55	1.7	5.2	5.0	5.4
Rope*[1]	6.21	13.20	36.08	14.30	10.1	20.0	25.9	24.5
Inflatable buoys*	--	--	--	5.94	--	--	--	2.0
Beverage crates	0.19	0.96	1.91	3.40	0.1	0.5	1.0	1.7
Gill net floats*	3.15	4.44	6.03	2.82	65.6	92.5	125.6	58.7
Bulk liquid containers*	0.53	0.92	3.21	2.10	1.2	1.9	5.4	1.5
Bottles	0.77	1.30	2.47	1.90	12.6	23.1	45.3	38.0
Plastic fragments	0.12	0.23	0.57	1.09	33.5	64.0	137.4	305.0
Fish baskets*	1.08	2.14	3.03	1.08	1.0	1.2	1.7	1.0
Polyvinyl sponge floats*	0.16	0.18	0.54	0.40	2.3	2.6	8.0	1.6
Sandals	0.36	0.22	0.31	0.30	3.0	1.8	2.6	2.5
Pails	0.20	0.22	0.44	0.23	1.1	1.3	2.6	1.0
Crab bait containers*	0.01	0.04	0.12	0.23	0.1	0.5	1.6	1.2
Lids and tops	0.07	0.07	0.14	0.18	11.9	13.0	25.0	33.2
Chemical ampules*	0.04	0.04	0.13	0.14	3.0	2.9	9.0	9.9
Cups and bowls	0.09	0.08	0.12	0.11	2.1	1.9	2.9	2.7
Strapping*	0.05	0.05	0.11	0.092	30.1	32.0	70.7	57.6
Outboard oil containers*	0.035	0.06	0.12	0.035	0.6	1.1	2.0	0.6
Six-pack yokes	0.003	0.006	0.01	0.023	0.6	1.1	2.0	4.5
Cigarette lighters	0	0	0	0.022	0	0	0	1.1
Cap visors	0.003	0.005	0.018	0.013	0.1	0.2	0.7	0.5
Shotgun cases	0.002	0.002	0.003	0.007	0.2	0.2	0.3	0.7
Total	121.64	156.42	345.42	225.23	193.2	283.1	498.4	588.9
Total excluding plastic fragments	121.52	156.19	344.85	224.14	159.7	219.1	361.0	283.9

[1]Length per kilometer: 1972 = 255 m; 1973 = 501 m; 1974 = 802 m; 1982 = 565 m.

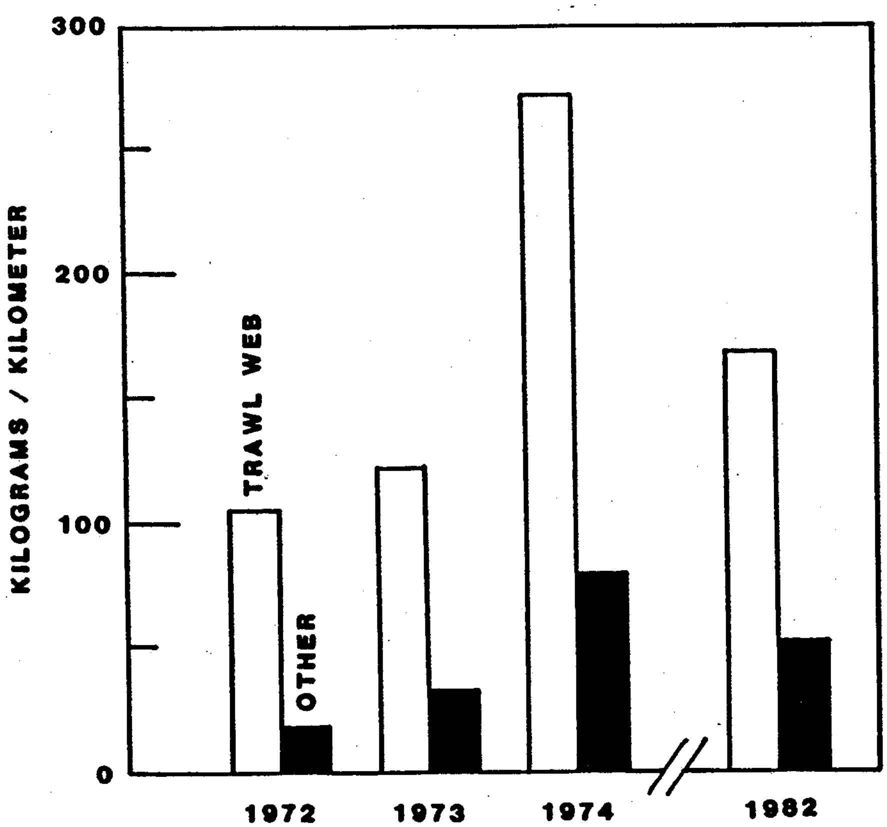

Figure 1.--Trawl web and other plastic litter on 10 Amchitka beaches, 1972-74 and 1982.

extension of U.S. fishery jurisdiction from 19 to 322 km (12 to 200 mi) offshore, the number of foreign trawlers declined 66%, to 232 trawlers in 1982 (Fig. 2). This large reduction was primarily a result of fewer Soviet vessels--from a peak of 377 vessels in 1972 to only 6 vessels in 1982.

It may be assumed that most trawl-web fragments are from Japanese fisheries, although the number of trawlers from other nations is increasing. In 1982, for example, over 80% of the foreign trawlers off Alaska were Japanese. Other percentages were: Republic of Korea 13%, U.S.S.R. 3%, Taiwan 2%, Poland 1%, and West Germany <1% (Hammond pers. commun.). The U.S. trawl fishery is rapidly expanding but has not been in existence long enough to contribute significantly to beach litter.

Because of this reduction in the trawl fishery, I expected smaller quantities of trawl web on Amchitka beaches in 1982 than in 1974. This was indeed the case--there was a 37% reduction in total weight of trawl-web accumulations on Amchitka beaches (from 272 kg/km in 1974 to 171 kg/km in 1982). During the same period, however, the number of trawl-web fragments increased, and the average weight of fragments decreased about 50%, from 11.5 to 5 kg per fragment.

Gill net floats do not cause entanglement, of course, but they do indicate the quantities of gill nets. On Amchitka Island, the number of gill net floats increased steadily between 1972 and 1974, then decreased by

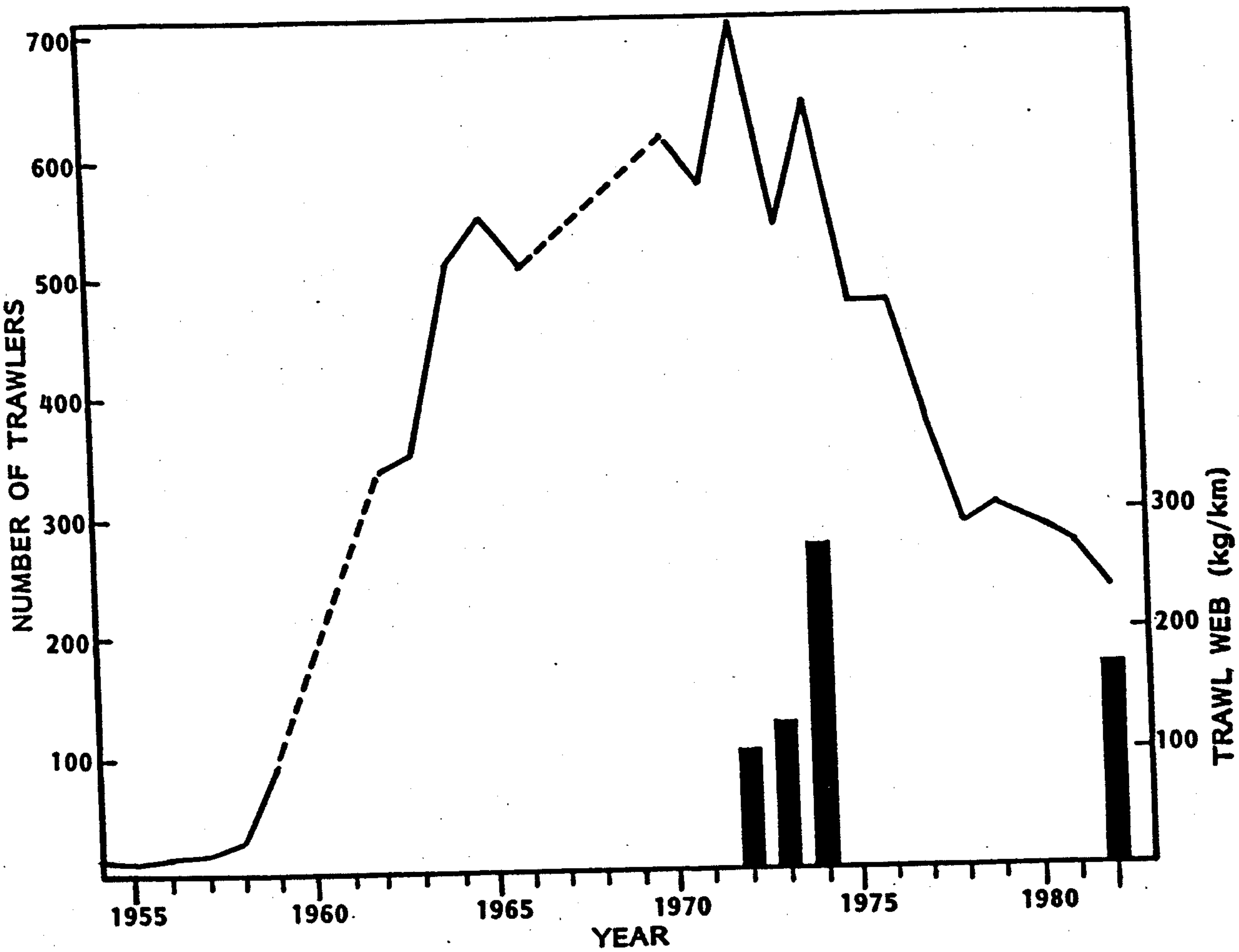

Figure 2.—Number of trawlers in the Bering Sea and northwest Pacific Ocean 1954-82 (solid and dashed lines) and weight of trawl web on Amchitka Island beaches (bars). Dashed lines are extrapolated for years with no Soviet trawl data. Source of data: 1954-59, Forrester et al. (1978); 1962-66, Chitwood (1969); 1970-82, J. C. Hammond pers. commun.

1982. Most gill net floats and nets on Alaska beaches probably originated from the long-standing Japanese high seas fisheries. For over 30 years, Japan has been the principal nation fishing with monofilament gill nets in the North Pacific Ocean and the Bering Sea, although Taiwan and the Republic of Korea have recently begun gill net fisheries for salmon and squid. There are three major Japanese gill net fisheres in the North Pacific Ocean and the Bering Sea (Fig. 3): (1) a mother ship fishery for salmon in the Bering Sea and the northern North Pacific Ocean, (2) a land-based fishery, also for salmon, south of the mother ship fishery, and (3) a fishery for squid, south of the land-based salmon fishery. A fourth large-mesh, gill net fishery for marlins and other pelagic species exists in the central and western Pacific Ocean but is not discussed here.

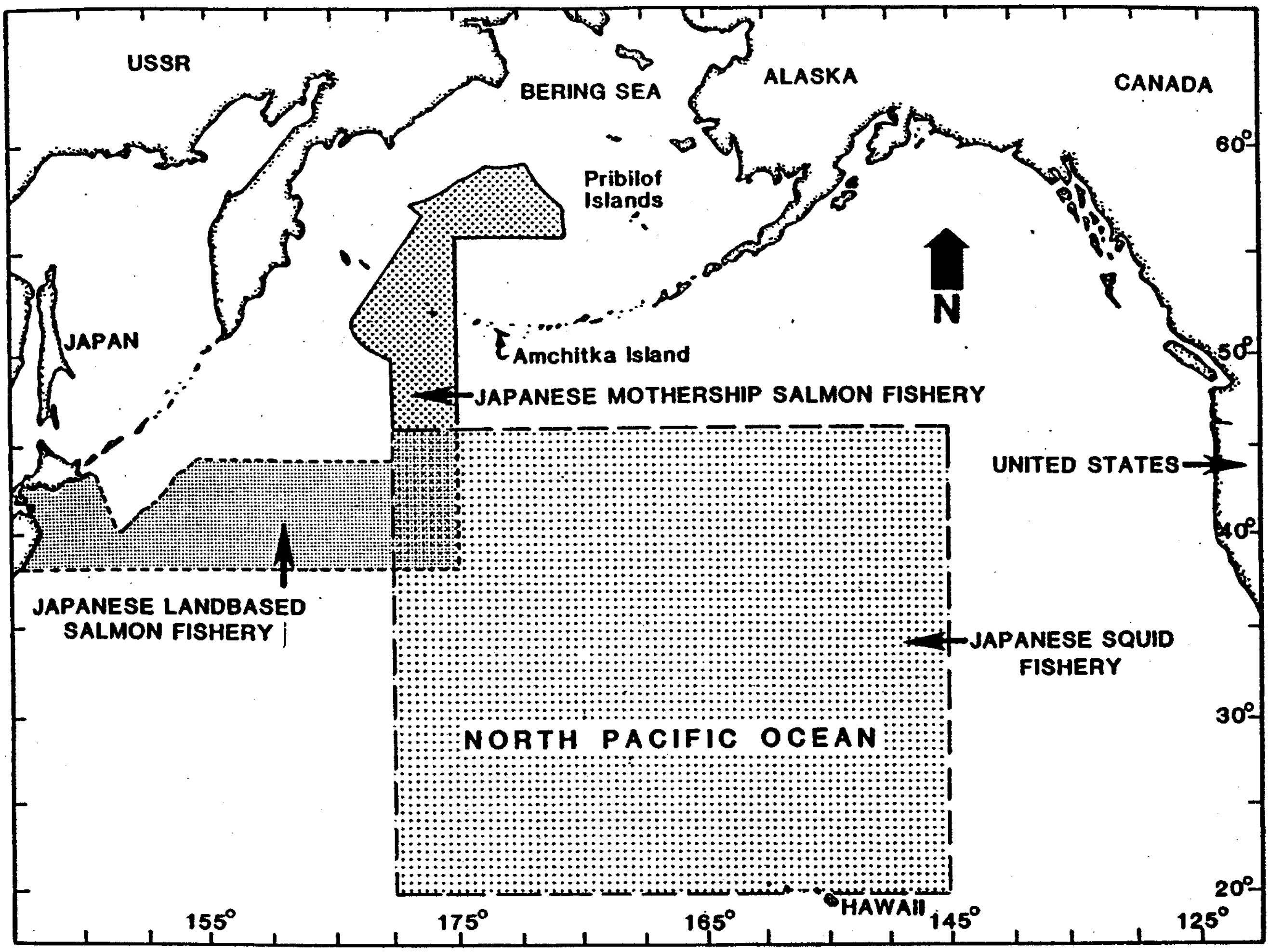

Figure 3.--Locations of Japanese mother ship and land-based salmon fisheries and squid fishery in the North Pacific Ocean and Bering Sea.

The area and number of gill nets fished in the Japanese mother ship fishery decreased greatly between 1974 and 1982 (Fig. 4). In 1977, the U.S.S.R. closed a large area to Japanese gill-netters off its coast in adjacent waters of the North Pacific Ocean and the Bering Sea. In the same year, the International North Pacific Fisheries Commission closed another midocean area between long. 175°E and 175°W and lat. 56°-46°N. In 1980, the number of Japanese salmon gill net boats was reduced nearly two-thirds in the area remaining open to fishing, from 447 boats in 1956 to only 172 boats. With fewer gill nets being fished and the elimination of gill-netting from a large oceanic area, the number of gill net floats on Amchitka beaches declined dramatically from 126/km of beach in 1974 to 59/km in 1982 (Fig. 5).

On the other hand, fishing effort in the Japanese land-based salmon and squid gill net fisheries is increasing, and Taiwan and the Republic of Korea have started new gill net fisheries for squid in the North Pacific Ocean. Little is known about these squid gill net fisheries, except that they are several times that of the combined Japanese mother ship and land-

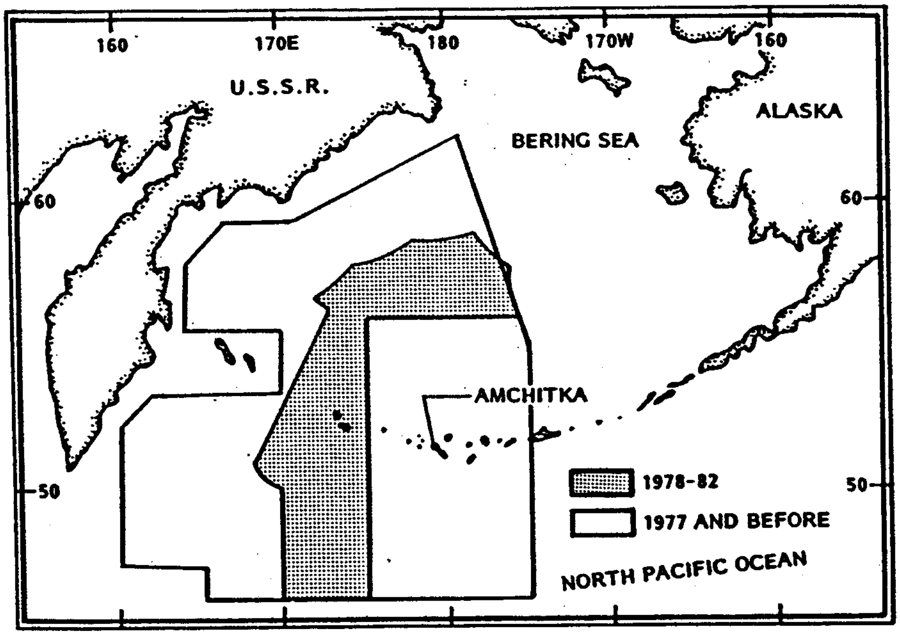

Figure 4.--Areas where Japanese salmon mother ship gill-netters fished in 1952-77 and 1978-82.

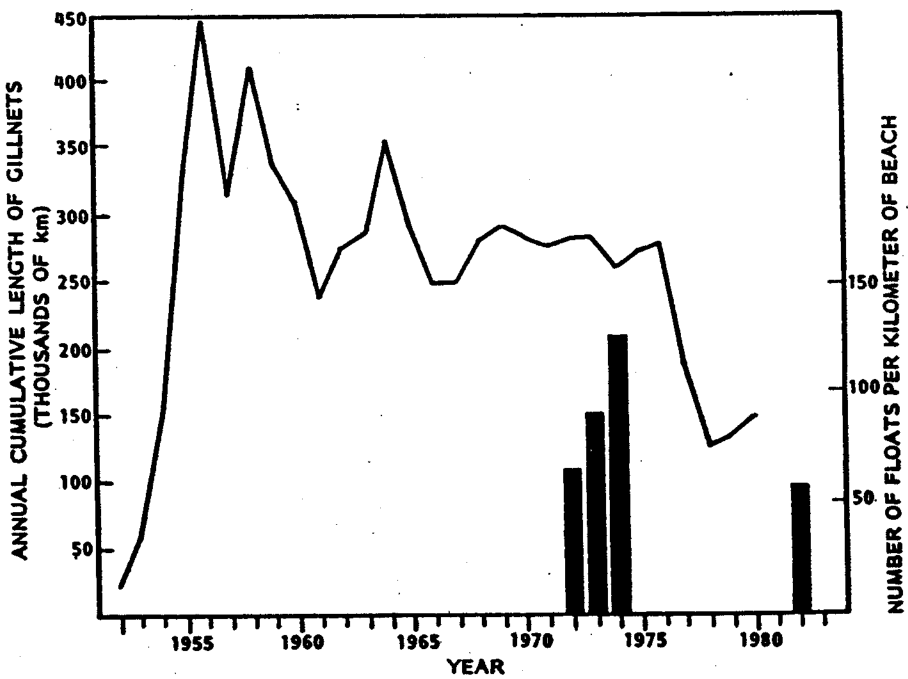

Figure 5.--Cumulative length (days by kilometers) of Japanese gill-netters in the salmon mother ship fishery (1952-80 (line) and number of floats on Amchitka Island beaches 1972-74 and 1982 (bars). Sources of data: 1952-77, Fredin et al. (1977), 1978-80, Michael L. Dahlberg (Auke Bay Laboratory, Natl. Mar. Fish. Serv., NOAA, Auke Bay, AK 99821, pers. commun.).

based salmon gill net fisheries and extend over a huge area of about 12 million km^2.

Plastic straps, used in trawl fisheries to bind boxes of frozen fish, nets, and other items for shipment, were also common on Amchitka Island. In 1982, straps were second only to gill net floats as the most abundant item. Coincident with the reduction in foreign trawl fishing off Alaska, there were 21% fewer straps on Amchitka beaches in 1982 than in 1974.

After my last surveys on Amchitka Island in 1982, there was increased concern about the numbers of marine animals entangled in litter, and in 1984, I was able to survey beaches at seven locations bordering the central and eastern Gulf of Alaska. Data from Amchitka Island indicated that the amount of litter from fisheries is roughly related to previous fishing effort. Because trawl fishing has decreased in the central and eastern Gulf of Alaska and is now prohibited east of long. 140°W and north of lat. 54°30'N off southeastern Alaska (Stauffer et al. 1983), I, therefore, hypothesized that there would be less fishery litter on beaches in southeastern Alaska.

As expected, trawl web and straps were less abundant in southeastern Alaska than on Amchitka Island, but there was a surprisingly large number of gill net floats, despite the fact that no high seas gill net fisheries have occurred nearby (Fig. 6). At two sites in southeastern Alaska, Middleton and Noyes Islands, the number of floats far exceeded the number at Amchitka Island. Many were weathered and had probably accumulated for years. The types and the proportion of other litter, however, were similar to those on Amchitka Island.

ENTANGLEMENT OF MARINE ANIMALS IN LITTER: IS IT A SIGNIFICANT PROBLEM?

Three types of plastic litter are known to entangle mammals, birds, and fish: trawl web, gill nets, and straps. There are many reports of marine mammals becoming entangled in trawl web but few data on the numbers of entangled animals that die. Shaughnessy (1980) has noted Cape fur seals entangled in trawl web in southern Africa breeding colonies since 1972, and Fowler (1982) concluded, on theoretical grounds, that as many as 50,000 northern fur seals die each year in derelict trawl-web fragments. At this workshop, there were several reports of other marine mammals found entangled in trawl web, including Steller and California sea lions, Hawaiian monk seals, northern elephant seals, and harbor seals.

Loss of discarded monofilament gill nets are also thought to significantly contribute to the entanglement problem, but evidence is lacking. I found only a few gill nets on beaches during the surveys, yet gill net floats were nearly always the most numerous plastic litter on the beaches. This is not surprising, perhaps because more than 2.5 million floats are in use in any year. Several questions must be answered before the extent of the gill net hazard can be assessed: How long after loss do gill nets pose an entanglement hazard? Do floating gill nets ball up soon after loss, thereby greatly reducing their entanglement potential? Do most nets eventually sink to the ocean bottom under the combined weight of leadline and entangled mammals, fish, and birds? (Once sunk, nets will

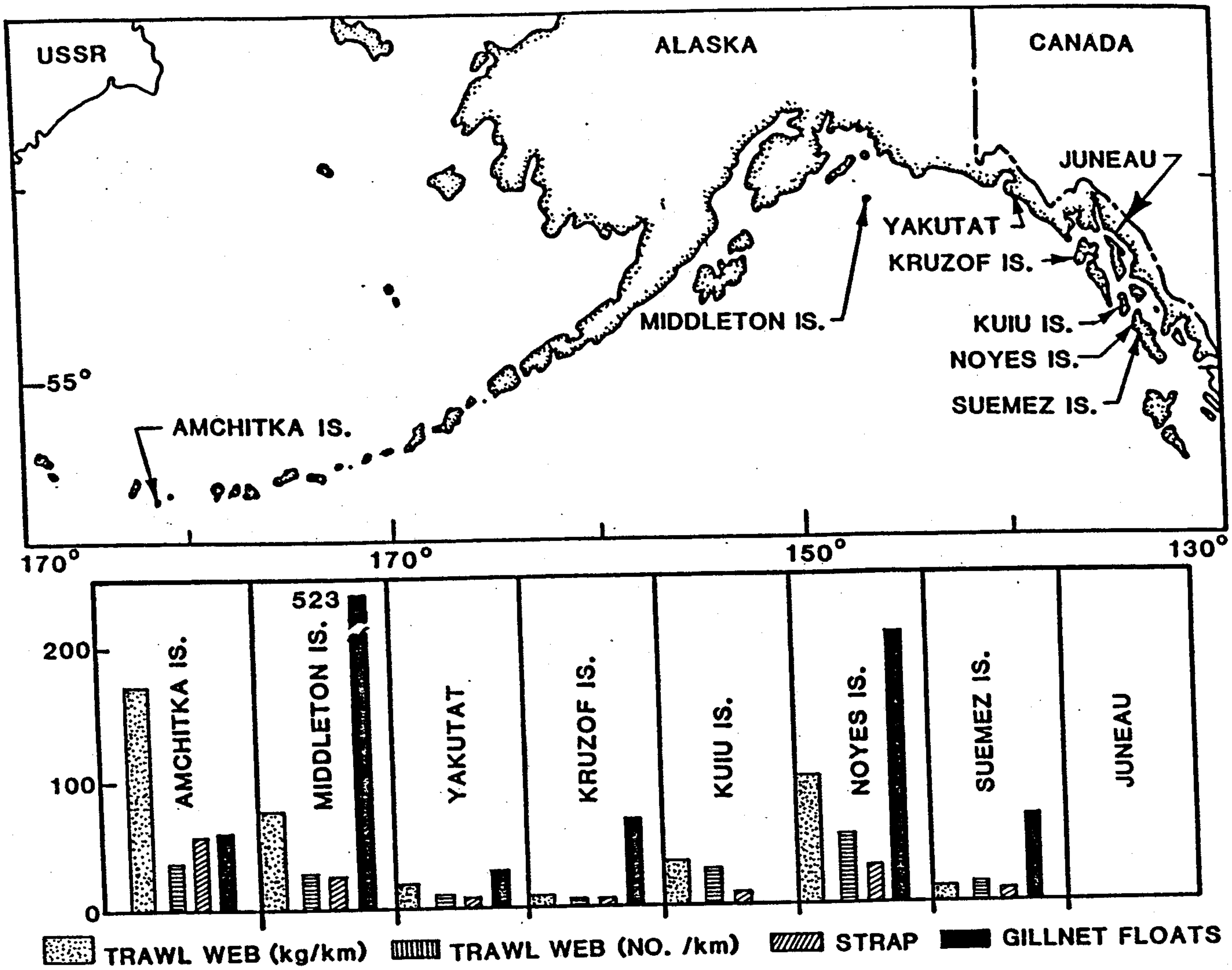

Figure 6.—Weight of trawl web and numbers of trawl-web fragments, strap, and gill net floats on beaches at Amchitka Island in 1982 and southeastern Alaska in 1984.

remain on the bottom because floats lose their buoyancy when permanently compressed by water pressure.) Why are gill net floats, unattached to net fragments or lines, nearly always the most numerous plastic litter item on beaches? How do floats come loose from the nets to which they are attached?

Straps, the third plastic litter item, form continuous loops (Fig. 7) that, if not cut before discarding, can entangle marine mammals. Six percent of the straps on Amchitka beaches in 1982 were uncut, and Fowler (1982) noted straps on about one-third of the entangled fur seals on the Pribilof Islands. Fur seals put their heads through the loops and are then unable to back out of them (Fig. 8). This source of entanglement could easily be eliminated if the straps were cut before being discarded.

Figure 7.--Uncut strap.

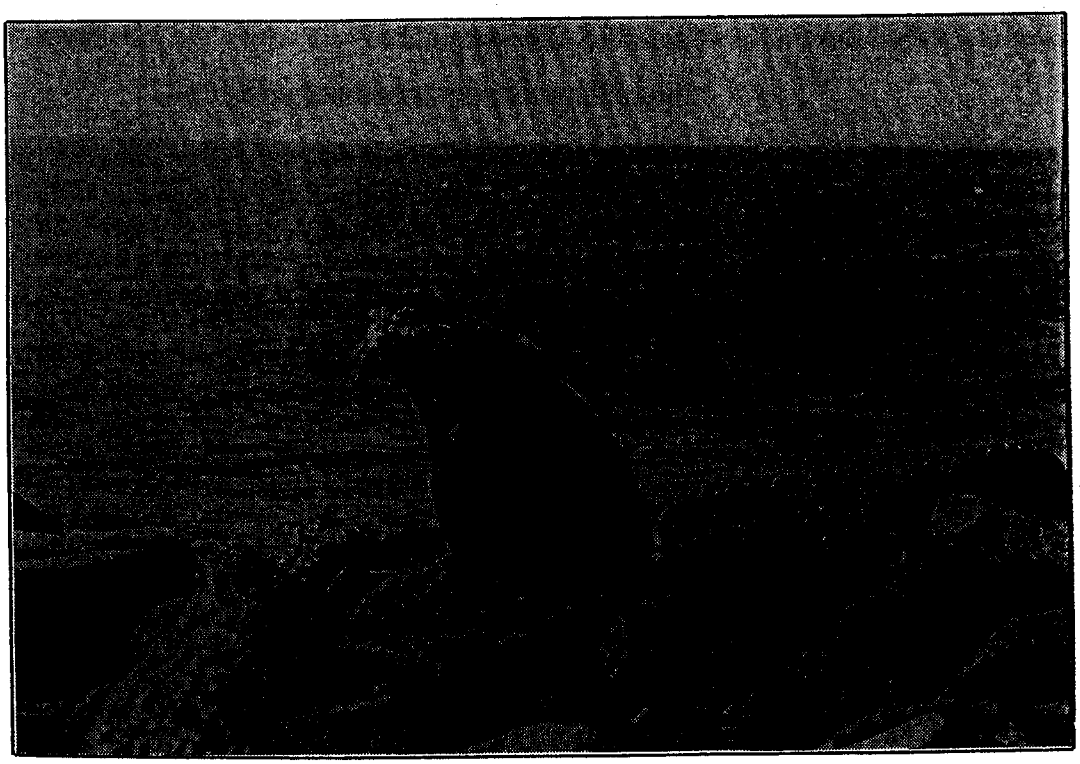

Figure 8.--Fur seal with uncut strap around shoulders, St. Paul Island, Pribilof Islands.

CAVEATS AND INTERPRETATION OF BEACH SURVEYS

Comparisons between the 1984 survey in southeastern Alaska and 1982 survey on Amchitka Island illustrate some of the problems affecting conclusions based on beach litter surveys (Fig. 6). For example, quantities of litter on beaches vary enormously, even on beaches with similar characteristics, such as Noyes and Kuiu Islands in southeastern Alaska. These islands are only about 32 km apart; both face southwest and have similar physical characteristics. Yet, compared to Kuiu Island, Noyes Island has about 4 times more trawl-web fragments, 10 times more trawl web (by weight), 4 times more straps, and 3 times more gill net floats. Middleton Island is another striking example of unevenly distributed litter. Beaches on the southern side of Middleton Island are awash in litter, whereas beaches on the northern side have almost none. Undoubtedly, tides, currents, and prevailing winds affect the distribution of litter. Thus, data from beach surveys should be used only for broad inferences. Quantities of litter are so variable and causes of variability so little understood that elegant statistical treatments are inappropriate and could be misleading.

Despite these caveats, some valuable insights can be gained from well-planned, carefully executed beach surveys. For example, based on gill net mesh sizes, I found that most of the gill net fragments on beaches in southeastern Alaska were from the land-based salmon and squid fisheries (Fig. 3). On 15 km of beach in southeastern Alaska, 21 fragments of gill net were found. Fourteen (67%) of these fragments were 110- or 115-mm stretch measure, which is the mesh size used in the Japanese land-based salmon and squid fisheries. Only three (14%) fragments were 120-mm stretch measure, the mesh size used by the Japanese mother ship fishery.

CONCLUSIONS AND RECOMMENDATIONS

I came to two conclusions from my surveys. First, beach surveys are a cost-effective method of assessing the quantities, types, and sources of litter and trends in accumulations, if surveys are standardized over measured sections of beach. Second, litter on beaches disappears quite rapidly if disposal or loss of litter at sea is reduced or eliminated.

Plastic marine litter could be drastically reduced if existing legal and regulatory mechanisms were used more effectively to control ship-generated litter. The principal international treaty regulating pollution of the marine environment by ships is the 1973 International Conference on Marine Pollution from Ships which is administered by the InterGovernmental Maritime Consultative Organization (IMCO). Annex V of this treaty limits the disposal at sea of plastics, including synthetic ropes and nets (IMCO 1977). As of 1 February 1985, only 21 countries, representing about 33% of the gross tonnage of the world's merchant shipping, have ratified Annex V. Japan, which has been one of the principal sources of plastic litter in Alaska waters, ratified the Annex V in October 1983, but none of the other countries with fishing fleets off Alaska (including the United States, U.S.S.R., Republic of Korea, and Taiwan) have done so. The North Pacific Fishery Management Council, which controls conditions under which fishing is permitted within 200 miles of the Alaska coast, could also be effective in reducing plastic pollution off Alaska. Ships could be required to retain aboard all garbage and scrap netting for shore disposal, as a condition for securing a fishing permit, and penalties could be imposed for violations.

Additional studies are needed: The countries that are sources of derelict fishing gear need to be identified, possibly by the physical and chemical characteristics of the gear itself. At present, this is usually not possible because most net material is manufactured in Japan and the nationality of the fishery that actually used a fragment of net cannot be determined. Distinctive chemical or visual tracers could be incorporated in nets during manufacture to identify the national origin, and nets could be designed so they would be less hazardous if lost. Future investigations of sources of derelict gill nets should probably place greater emphasis on land-based salmon and squid fisheries than on the mother ship salmon fishery. Beach surveys should be expanded to determine which regions have the greatest concentrations of litter. Experiments should be conducted with marked debris on beaches to determine whether most litter stays ashore once stranded. Finally, we need to inform fishermen that carelessly disposed nets and straps can trap and kill marine animals.

ACKNOWLEDGMENTS

I gratefully acknowledge the help of Sidney Taylor, Robert Budke, and especially Scott Johnson in making the 1984 surveys. The Marine Mammal Commission provided travel funds for the 1984 Alaska beach litter surveys and a part of my expenses to attend this workshop; neither would have been possible without this assistance.

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APPENDIX

INSTRUCTIONS FOR SURVEYING BEACHES AND RECORDING DATA

Careful preparations should be made before surveys begin. These preparations include: (1) precisely defined objectives, (2) detailed, explicit instructions on methods and procedures, (3) portable marking, weighing, and measurement equipment, and (4) large-scale maps of beach survey sites.

Equipment for beach surveys (available from Forestry Supplies, Inc., P. O. Box 8397, Jackson, MS 39204) is simple, inexpensive, and easily carried: a Hip-chain[1] to measure length of beach surveyed (Fig. A-1); a

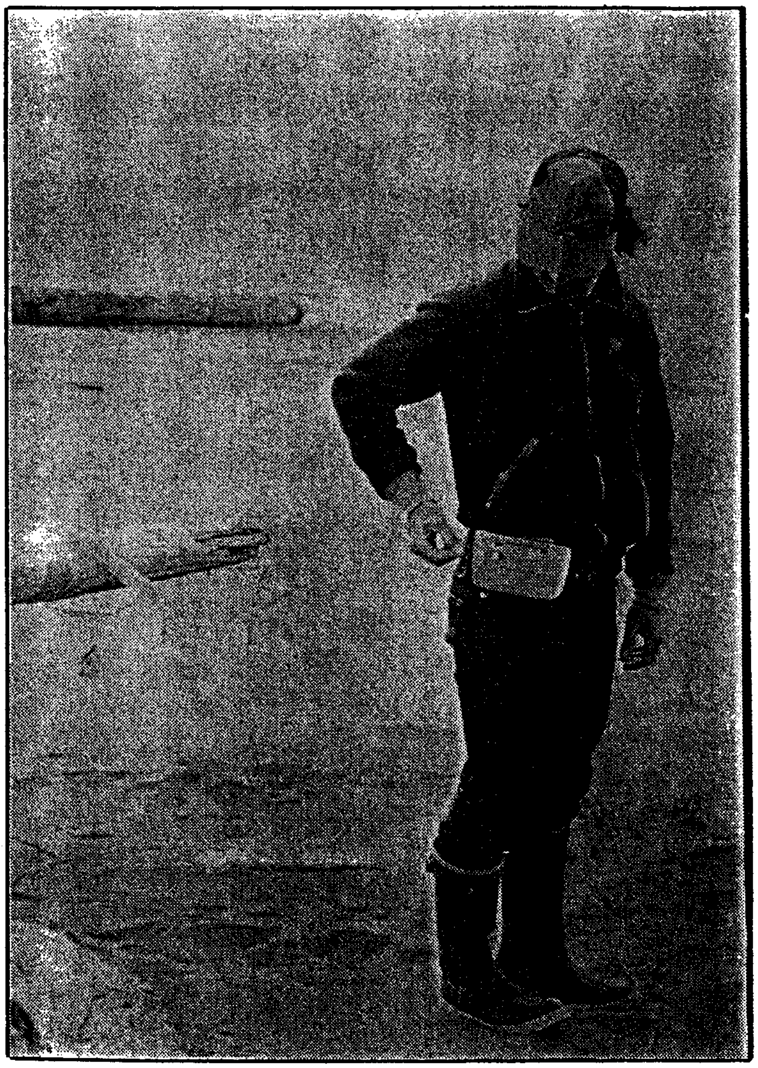

Figure A-1.--Adjusting Hip-chain to begin measurement of beach survey.

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Trecoder Spotgun with orange dye to mark boundaries of beach surveys (Fig. A-2); a set of Pesola precision spring scales, 50 to 20 kg, to weigh fragments of netting and other debris (Fig. A-3); surveyor's fluorescent flagging tape; a clipboard with water-resistant, preprinted forms; No. 2 lead pencils; and 1:62,500 U.S. Geological Service quadrangle maps.

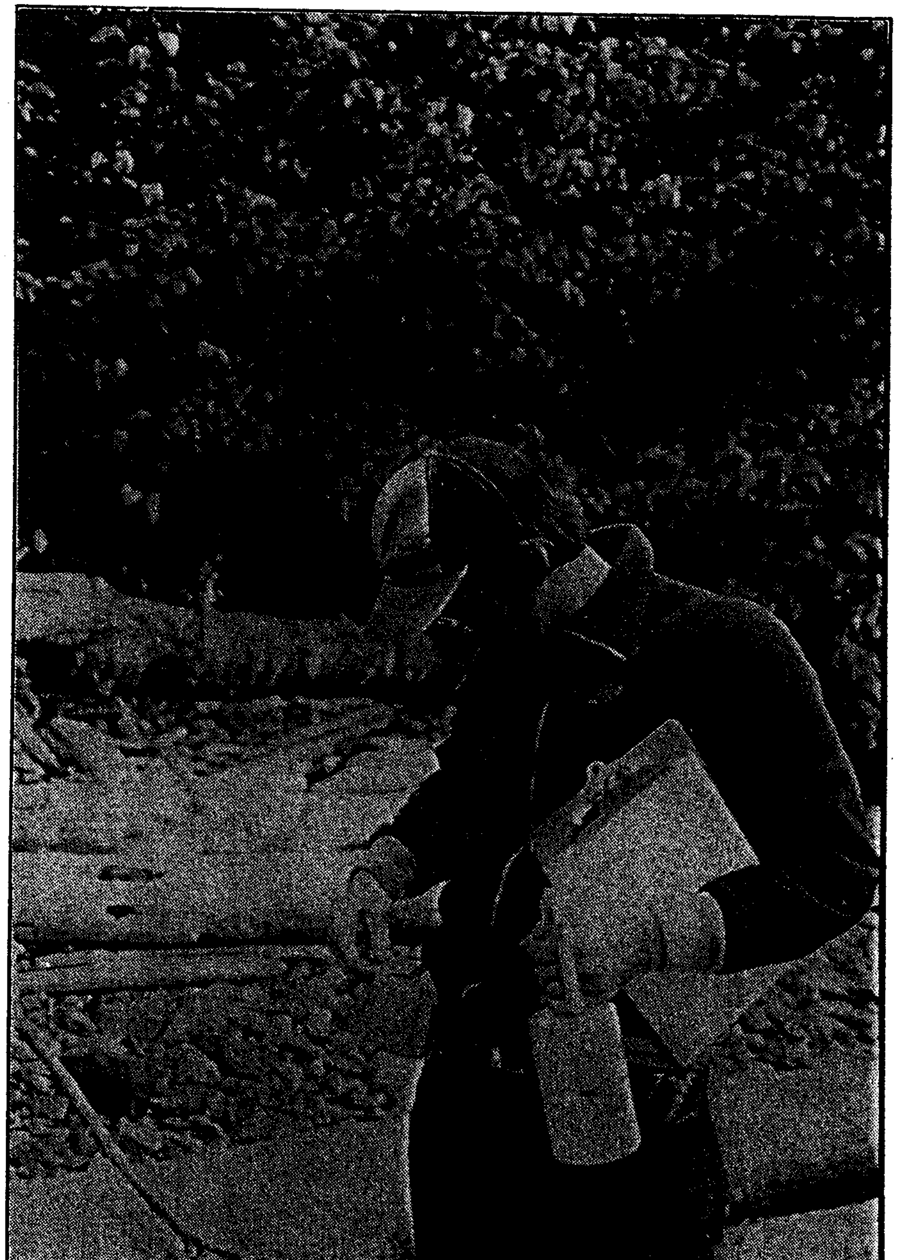

Figure A-2.--Trecoder spotgun with ink reservoir and form on clipboard, left hand.

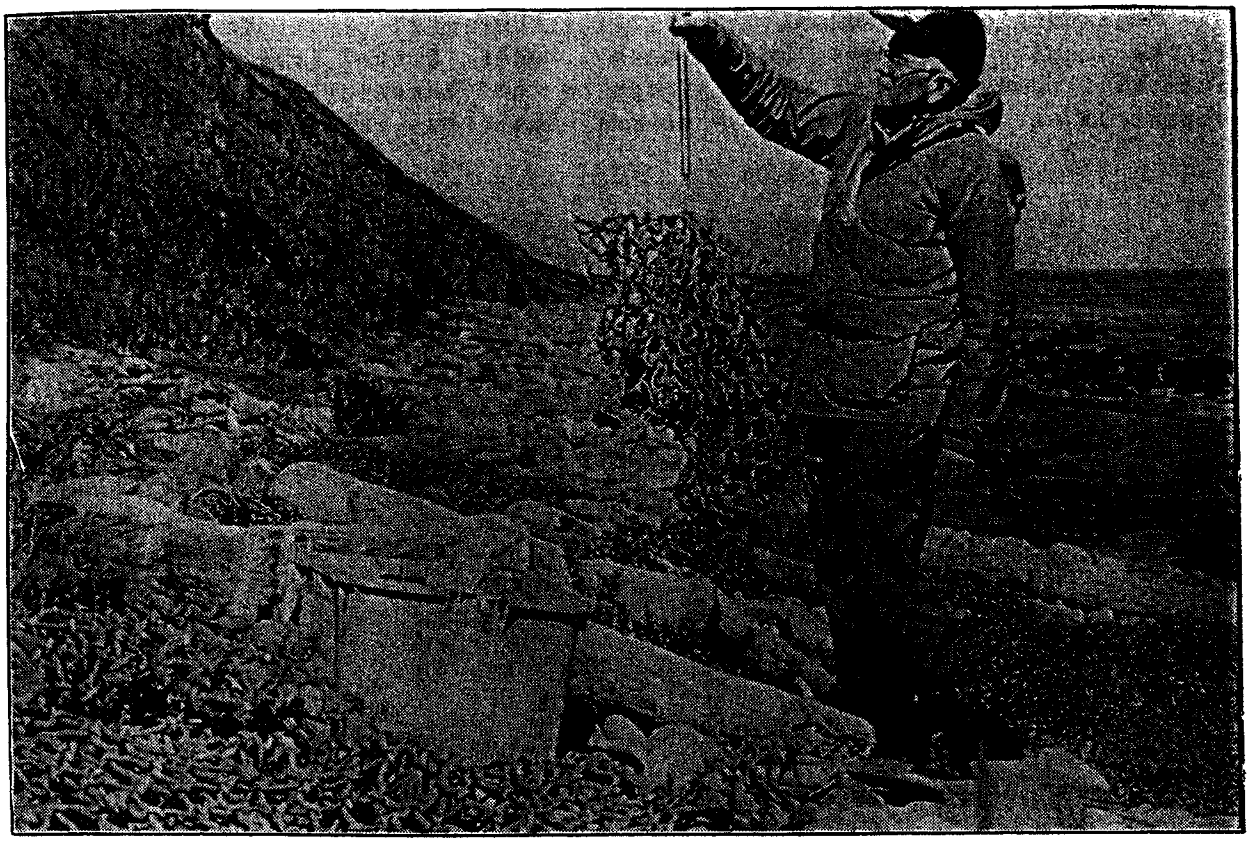

Figure A-3.--Weighing trawl-web fragment with Pesola spring scale.

SELECTING BEACHES

Preferred beaches for litter surveys are moderate to steep, sand or gravel beaches that are exposed to the open sea. The beaches should have at least 1 km of similar substrate and slope and be as far as possible from urban areas to minimize bias from local garbage. Low-gradient beaches are unsuitable because storm winds and surf scatter litter inland, where it becomes hidden in vegetation. Boulder, as well as bedrock, beaches are also unsuitable: Litter in crevices between boulders is difficult to see, bedrock beaches are often too steep to walk on, and litter does not accumulate there.

MARKING AND DESCRIBING THE BEACH

Estimate, or preferably measure with a Hip-chain, the length of beach surveyed so that litter data from beaches of different lengths can be quantitatively compared. If possible, one end of the beach survey should be a permanent landmark (e.g., river mouth, rock outcrop, tree, or building). Permanently mark each end of survey with dye and surveyor's flagging. Write a brief description of the beach, mark the location on a large-scale map, and photograph the marked ends of the beach so the survey section can be relocated easily.

SURVEY METHODS

Depending on the amount of litter, it normally takes from 4 to 16 h for two people to survey 1 km of beach. Count litter items within the intertidal zone, from the water's edge to the seaward limit of terrestrial vegetation at the upper limit of normal high tide (Fig. A-4). Most litter

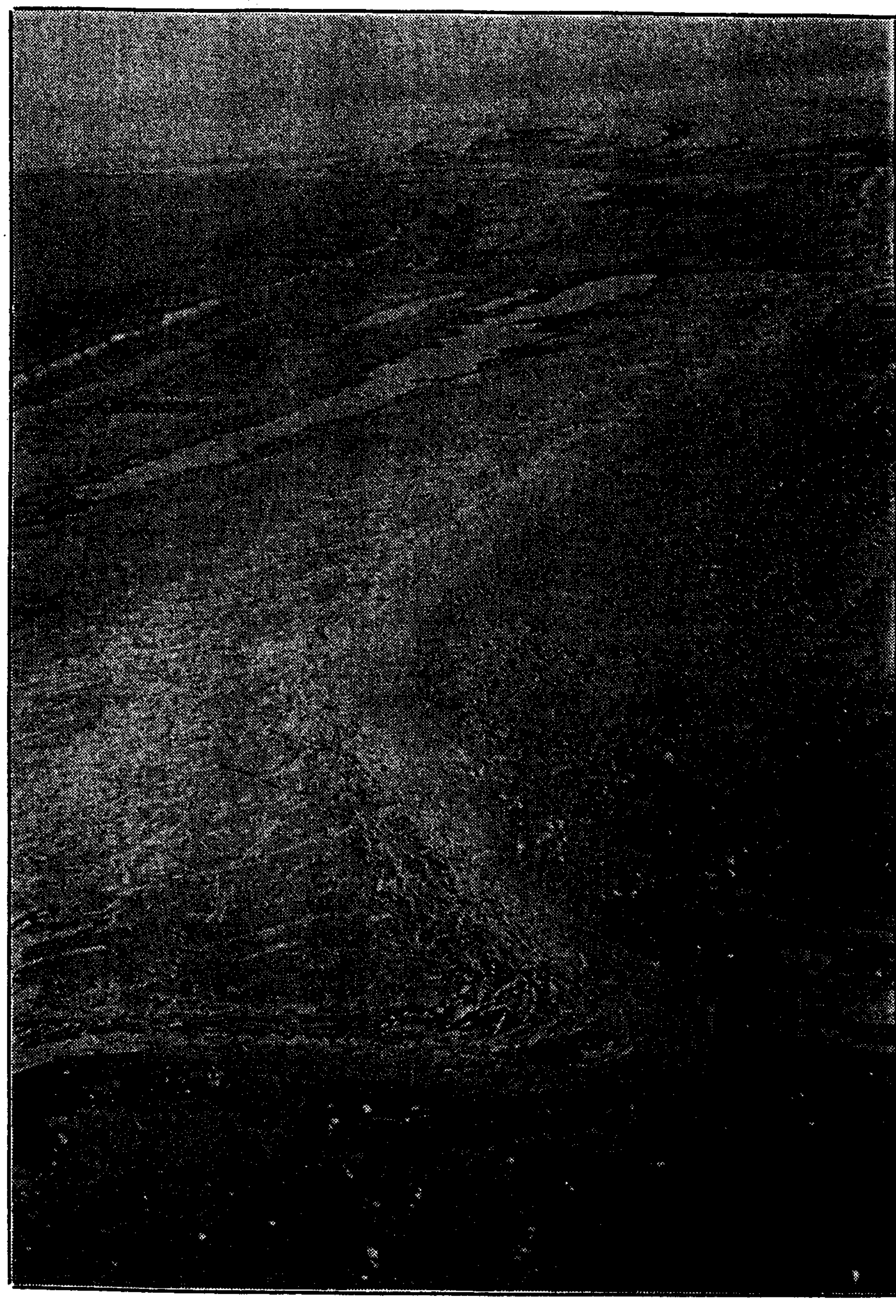

Figure A-4. Limits of intertidal survey area at Middleton Island, Gulf of Alaska: from edge of water (bottom and right of photo) to upper limit of normal high tide (center, where driftwood is concentrated). Extreme storm tides scatter litter across the lowland, which is vegetated to the bluff (upper left), but this area is not included in surveys.

is concentrated near the upper limit of normal high tides. Count all plastic items visible from a walking height (i.e., anything larger than about 5 mm). Do not search for litter within piles of driftwood (Fig. A-5). Tabulate and estimate the weight of only the visible portion of net fragments (Fig. A-6); ignore the buried portion. Do not dig or pull out net fragments partially buried in sand, driftwood, kelp, or cobbles. If a snarl of several sizes of netting cannot be separated, estimate the weight of each size (Fig. A-7).

INSTRUCTIONS FOR RECORDING OBSERVATIONS

See Figure A-8 for an example of a completed beach litter survey form. Use metric system for all measurements.

Right Margin

A metric scale is printed for measuring mesh sizes, twine diameter, etc.

Upper Left Heading

Name of surveyor(s) and date of survey.

Figure A-5.--Driftwood with trawl-web fragment in foreground. Information is recorded only for litter visible on the surface.

Figure A-6.--Trawl-web fragment partially buried in beach sand. Information is recorded only for portion which is visible.

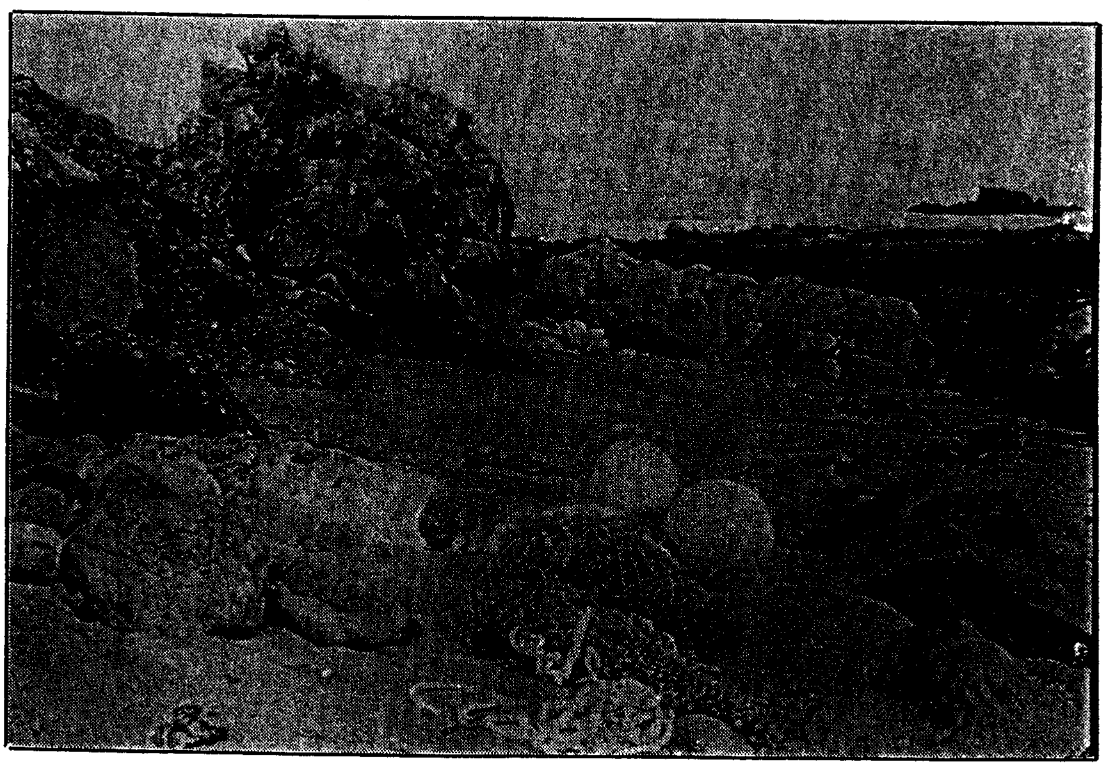

Figure A-7.--Snarl of several sizes of trawl web. For each, mesh sizes are measured, but weights are estimated.

BEACH LITTER SURVEY

Sheet 2 of 3

Name of Surveyor Scott Johnson
Date of Survey 7/14/84
Location: Middleton Island
USGS Quad. Middleton Island
Lat. ______ Longitude ______

Length of Beach (m) 1000
Sand ______
Gravel ✓
Boulder ______
Time noon to 8:30 pm

ITEM	PART FRAG	WT. kg (Est.)	STRETCH MESH (mm)	TWINE (mm)	COLOR	REMARKS	TOTAL EACH ITEM
TRAWL WEB		1.2 kg	235	3	B		1
	✓	(300 g.)	50	5	BK	Under log	1
	✓	(400 g.)	200	3	G	In gravel	1
	✓	(100 g.)	70	5	Orange	Braided Knotless mesh	1
		.45 kg	110	2	B		1
* STRAPS - OPEN		Y	B 1	W	R	G 1	2
CLOSED (cm. stretch)		1-50 cm					1
TRAWL FLOATS (cm. o.d.)		24 cm. BK	30 cm Orange	26 cm BK			3
		26 cm BK					1
SYNTHETIC LINE (diameter & length)		16 mm-5 m	19 mm-1 m	35 mm-5 m	13 mm-1 m	35 mm-5 m, 6 mm-1 m	6
		10 mm-1 m	16 mm-2.5 m	19 mm-1 m			3
BAIT CONTAINERS		|					1
GILLNET FLOATS		卌 卌 卌 卌 卌 ||||					29
BOTTLES		卌 卌 卌 卌 ||||					24
CAPS and LIDS		卌 卌 ||					12
FRAGMENTS - HARD		卌 卌 卌 卌 ||||					24
SOFT		卌 |||					8
BUOY BAGS		卌					5
OTBD. OIL CONTAINERS		||					2
6-PACK YOKES		|					1
Visqueen < 1 m²		|||					3
Styrofoam		卌 卌 卌 |					16
Mono gillnet		Small wad, no floats - 55 mm				stretch mesh	1
Pail							1
Beverage crate		1-Kirin Beer	1-Asahi Beer			1-Mitsuya cider	3

HIFU 5/84

* G = GREEN R = RED Y = YELLOW
W = WHITE B = BLUE BK = BLACK

TOTAL ITEMS THIS SHEET 151

Figure A-8.--Example of completed beach litter survey form.

General location (e.g., 10 km south of Yakutat).

U.S. Geological Survey 1:63,500 quadrangle name (e.g., Yakutat B-5).

Specific location (latitude and longitude, etc.).

Upper Right Heading

Number each sheet and total number of sheets for each beach (e.g., Sheet 1 of 3).

Shoreline length of beach.

Check predominant composition of beach (sand, gravel, or boulder).

Beginning and ending times of survey.

Trawl Web

Use separate line for each fragment. Weigh and measure any fragment that has one or more complete meshes.

For partial fragments ("Part. Frag.").--Enter a check (✓) mark for each piece of webbing which is partially buried or tangled and weight of entire fragment cannot be determined; estimate weight of exposed portion only.

Weight (Wt.).--Select spring scale with appropriate range and weight to nearest whole scale marking. Obtain accurate weights of small fragments, especially <1 kg. Indicate "g" for grams or "kg" for kilograms for each weight.

Stretch mesh.--Knot to knot inside measure of one representative mesh, stretched tight.

Twine.--Diameter of mesh twine in millimeters (mm).

Color.--Indicate mesh color by symbol: G = green, W = white, R = red, B = blue, Y = yellow, BK = black.

Remarks.--Additional comments, e.g., "snarl of mixed mesh sizes and colors" or "weights of individual fragments in snarl not estimated."

Strap

Indicate strap color by symbol as above (Trawl Web section).

Open.--Stroke tally number of cut (open) straps, each color.

Closed.--Measure inside length of each strap stretched tight (equals one-half strap length). Use separate block for each strap.

Trawl Floats

Indicate diameter (often marked on float) and color.

Use separate block for each float.

Synthetic Line

Estimate or measure diameter and length of each piece. Use separate block for each piece.

Bait Containers

Stroke tally each container. Several types are used and can be recognized by numerous small holes drilled or moulded in sides of container.

Gill Net Floats

Stroke tally each whole float or fragment greater than one-half. Tally each float less than one-half as a "hard fragment."

Bottles

Stroke tally plastic containers, collectively lumped under the terms "bottles." Do not count tops or lids separately if on container.

Caps and Lids

Stroke tally those that are not on containers.

Fragments[2]

Stroke tally hard and soft fragments separately. This category defies precise definition. It is a subjective catchall for broken pieces of larger items. Most are small. Include any fragment less than half the original item. Arbitrarily decide whether it is "hard" or "soft" plastic. Most soft fragments are bits of synthetic line, trawl web composed of less than one complete mesh, or seine twine. Hard fragments are bits of gill net floats, buckets, etc.

Buoy Bags

Stroke tally without differentiating size. These are inflated commercial fishing floats, usually orange with dark blue tapered tip.

Outboard Oil Containers

Stroke tally without differentiating size (some are imperial quarts and some are U.S. quarts).

Six-Pack Yokes

Stroke tally.

Miscellany

Use blank lines at bottom of form for additional items not on printed list. Continue remarks on reverse of form to describe unusual litter.

---

[2]This classification has not yielded useful information and is time consuming--may be omitted.

Describe gill net wads, indicating mesh material (monofilament or multifilament nylon), float material (hollow or sponge plastic), color, number and type of floats, stretch-mesh size, weight (actual or estimated), whether corkline and leadline are single or double, and if leadline is lead-core or with attached leads. Also describe and photograph remains of any mammals, fish, or birds.

After completing each survey, immediately check information recorded on form to make sure all data are complete and legible. Add totals for each item on each sheet and record sum in right column; add totals of all items on each sheet and record sum at bottom of sheet, lower right.

OBSERVATIONS OF NET DEBRIS AND ASSOCIATED ENTANGLEMENTS IN THE NORTH PACIFIC OCEAN AND BERING SEA, 1978-84

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ABSTRACT

Since 1978, observers collecting marine mammal sighting data in the North Pacific Ocean and Bering Sea during the period May to August have also recorded sightings of discarded net debris and entangled animals. Sightings of net debris were made between lat. 38°28' and 57°31'N and between long. 151°28'W and 179°35'E. Of the net fragments that could be identified, three were trawl web, ranging in size from about 1 m to larger pieces of indeterminate size, and six were gill net, 20 to 150 m long. Two trawl net fragments had a total of three entangled northern fur seal, Callorhinus ursinus, but no marine mammals or other animals were observed in the remaining pieces. One other northern fur seal was observed with a small piece of gill net around its neck. In addition observers reported four instances of discarding of gill net fragments by fishing vessels.

Three abandoned gill nets were observed outside the western North Pacific fishing areas in 1978 and 1981. One of these was retrieved by a research vessel off Agattu Island, Alaska. Although there were no marine mammals, several hundred seabirds and salmon were entangled.

During this study, data on most sightings of net debris were collected incidentally. However, during five cruises in 1982-84, observers did search for net debris and record all sightings. During the 1984 field season, all marine mammal observers (n = 20) in the western North Pacific conducted searches for net debris during daylight transits. In addition, personnel aboard NOAA vessels began recording debris sightings in the eastern North Pacific. These data are being used to examine the distribution and to quantify the abundance of net debris. To date during 304 h of survey, there have been two sightings of gill net and one of trawl net fragments. This low incidence may be associated with difficulties in sighting debris or a low occurrence of floating debris in the area during this time of year. Marine mammal observers will continue search efforts for net debris and net entanglements during the 1985 and 1986 field seasons.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

INTRODUCTION

Two sources of potential entanglement of marine mammals and birds are fishing gear in active use and lost or discarded gear. Information concerning the latter is limited. Dixon and Dixon (1981) described three methods of obtaining information on the distribution, amount, and composition of litter in the ocean: estimation from the average amounts per day generated by various kinds of activities such as fishing or pleasure boating; observation of floating debris at sea; and surveys of litter on selected beaches.

Beach surveys have provided most information to date due to relative ease of conducting the work and cost effectiveness (Anonymous 1973; Cundell 1973; Dixon and Cooke 1977; Dixon 1978; Merrell 1977, 1980, 1981; Dixon and Dixon 1981; Fowler et al. 1982). This method, however, does not necessarily provide an accurate measure of the kind or amount of debris floating in the ocean.

Data have been collected at sea using surface tows (Carpenter and Smith 1972; Colton et al. 1974; Wong et al. 1974) and benthic trawls (Jewett 1976; Feder et al. 1978). These have provided information on plastic particles and miscellaneous debris but only limited information on net debris. DeGange and Newby (1980) reported one instance of a lost gill net in the western North Pacific Ocean. The only data on floating debris collected by sighting surveys during vessel transits are provided by Venrick et al. (1973) in the central North Pacific Ocean and Morris (1980) using similar methods in the Mediterranean Sea. Neither reported sighting net fragments.

Concern over incidental catch of marine animals has been expressed for turtles (Morris 1980), sharks (Anonymous 1977), seabirds (Tull et al. 1972; Bourne 1977; King et al. 1979), Cape fur seals (Shaughnessy and Payne 1979; Shaughnessy 1980; Bonner and McCann 1982), baleen whales (Perkins and Beamish 1979), small cetaceans (Best and Ross 1977), and northern fur seals (Waldichuck 1978; Kozloff 1979; Fowler 1982; 1985).

This paper summarizes data collected on net debris and associated entanglements in the western North Pacific Ocean and southern Bering Sea from May-August 1978 to 1984. These data provide quantitative information on the amount of net debris present in these areas during the summer, and comparisons between years may be possible. Data from two cruises in the eastern North Pacific are also included.

METHODS

Most data were obtained by United States biologists collecting marine mammal sighting data on Japanese salmon research vessels under the United States-Japan cooperative research program on Dall's porpoise. Each year Japan conducts salmon research in the North Pacific from long. 150°E to 175°W. Vessel tracks are at intervals of about 5° longitude. Since 1978, data have been collected by United States biologists on Japanese salmon research vessels operating from May to August along standard track lines between lat. 38° and 57°N in the western North Pacific Ocean and southern Bering Sea. Beginning in 1981, United States biologists were also placed aboard commercial fishing vessels of the Japanese mother ship salmon fleets operating from 10 June to about 31 July. Eight United States observers were aboard catcher boats each day and collected marine mammal sighting data during transits to and from the mother ship (Fig 1).

The biologists were trained at the National Marine Mammal Laboratory (NMML), Northwest and Alaska Fisheries Center, Seattle, Washington, to conduct marine mammal sighting surveys using the standard methods of the NMML Platforms of Opportunity Program. Observations were made from the flying bridge of the vessel and the forward 180° arc was scanned. Surveys were generally conducted when visibility was greater than 1,000 m and the sea state was Beaufort 4 or less. These are termed "on-effort" data and are used for quantitative estimates of marine mammal populations. Under less favorable conditions and during fishing operations (e.g., setting or retrieving gill nets), sightings were recorded but were considered "off-effort" and used only for determining distribution and seasonality.

During the period 1978 to 1983, data on net debris, abandoned gill nets, and associated entanglements were recorded inconsistently. Starting in 1984, biologists were instructed to search for and record all observations of net debris, including date and time of sighting, longitude, latitude, type and amount of gear, and the number and species of animals entangled. Binoculars (7 x 50 or 10 x 50 power) were used to obtain details of the sighting. The sizes of the fragments were estimated as the ship passed by them.

RESULTS

A total of 1,768.5 nmi were transitted during 196.5 h of "on-effort" observation for net debris during cruises in the period from 1978 to 1983 in the western North Pacific (Table 1). Two sightings of net debris were made: a trawl fragment at lat. 52°N and long. 170°E and a gill net fragment at lat. 38°N and long. 174°E (Fig. 2). There were no marine animals entangled in these net fragments (Table 2).

In 1984, 20 observers logged 973.2 h on "on-effort" surveys covering 7,559 nmi in the western North Pacific and 1,200 nmi in the Bering Sea, north of lat. 53°N. Three sightings of trawl net pieces were made; each piece was about 2 m in size. There were also nine sightings of gill net fragments ranging in size from <0.5 to 150 m (Table 2 and Fig. 2). No animals were entangled in these fragments. Four sightings of discarded gill net were within the mother ship salmon fishing area. Five sightings were in the area of the squid gill net and Japanese land-based salmon fisheries (Table 2).

In addition to those described above, 30 sightings of net debris during "off-effort" observations have been recorded. Four of these were trawl nets, 20 were gill nets, one had trawl and gill net fragments, and the remainder were not identified (Fig. 3). Of the trawl net fragments, two had a total of three entangled northern fur seal, Callorhinus ursinus. Two northern fur seals, 1 salmon shark, Lamna ditropis, 11 birds (various species), and an unknown number of salmon were also entangled in gill net fragments. The size of the gill net pieces ranged from 0.5 to 200 m.

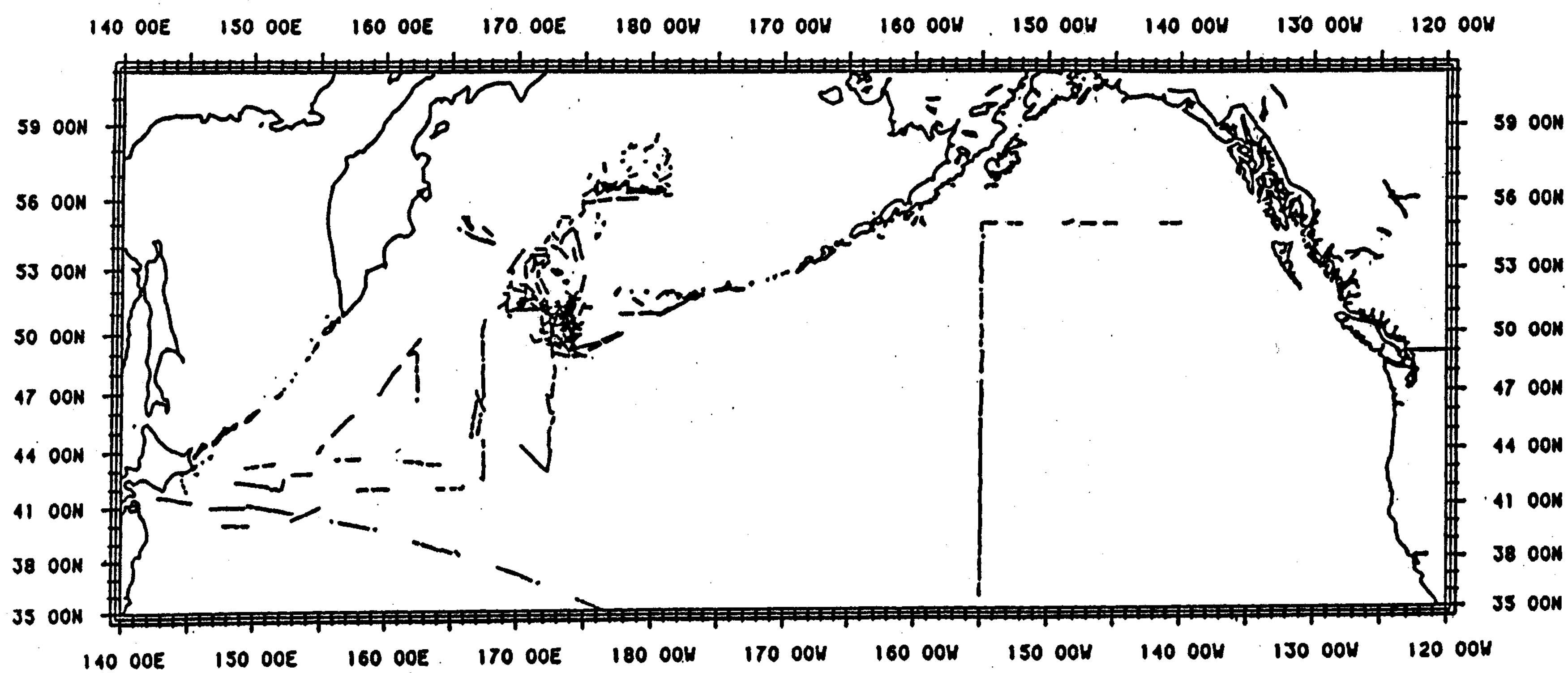


Figure 1.--Cruise tracks during observations for net debris and entanglement, 1978-84.

Table 1.--Hours of effort searching for net debris by Beaufort sea state, distance covered, and number sightings "on effort" of net debris (in parentheses).

Dates	No. of observers	Type of vessel	Distance covered (nmi)	Area[1]	Beaufort state 0	1	2	3	4	5	6	Total hours	No. of sightings
1982-83	2	Commercial	1,138.5	WNP	0	8.0	32.0	56.5(1)	24.0	6.0	0	126.5	1
1983	1	Research	630.0	WNP	0	1.5	17.0	9.0(1)	29.5	9.5	3.5	70.0	1
1984	16	Commercial	3,561.0	WNP	11.3	35.1(1)	90.2	180.2(2)	71.5	8.4	0	396.7	3
1984	8	Commercial	1,085.0	BS	4.8	8.0	34.1	41.5	25.9	2.4	0	116.7	0
1984	4	Research	4,113.4	NP	10.4	48.8(1)	118.1(4)	153.4(4)	87.4	36.0	2.9	457.0	9
Sightings per hour of effort (x^{10-2})					0.0	1.97	1.37	1.82	0.0	0.0	0.0		

[1]Abbreviations: WNP = western North Pacific Ocean; BS = Bering Sea, north of lat. 53°N; NP = North Pacific Ocean including eastern and western areas.

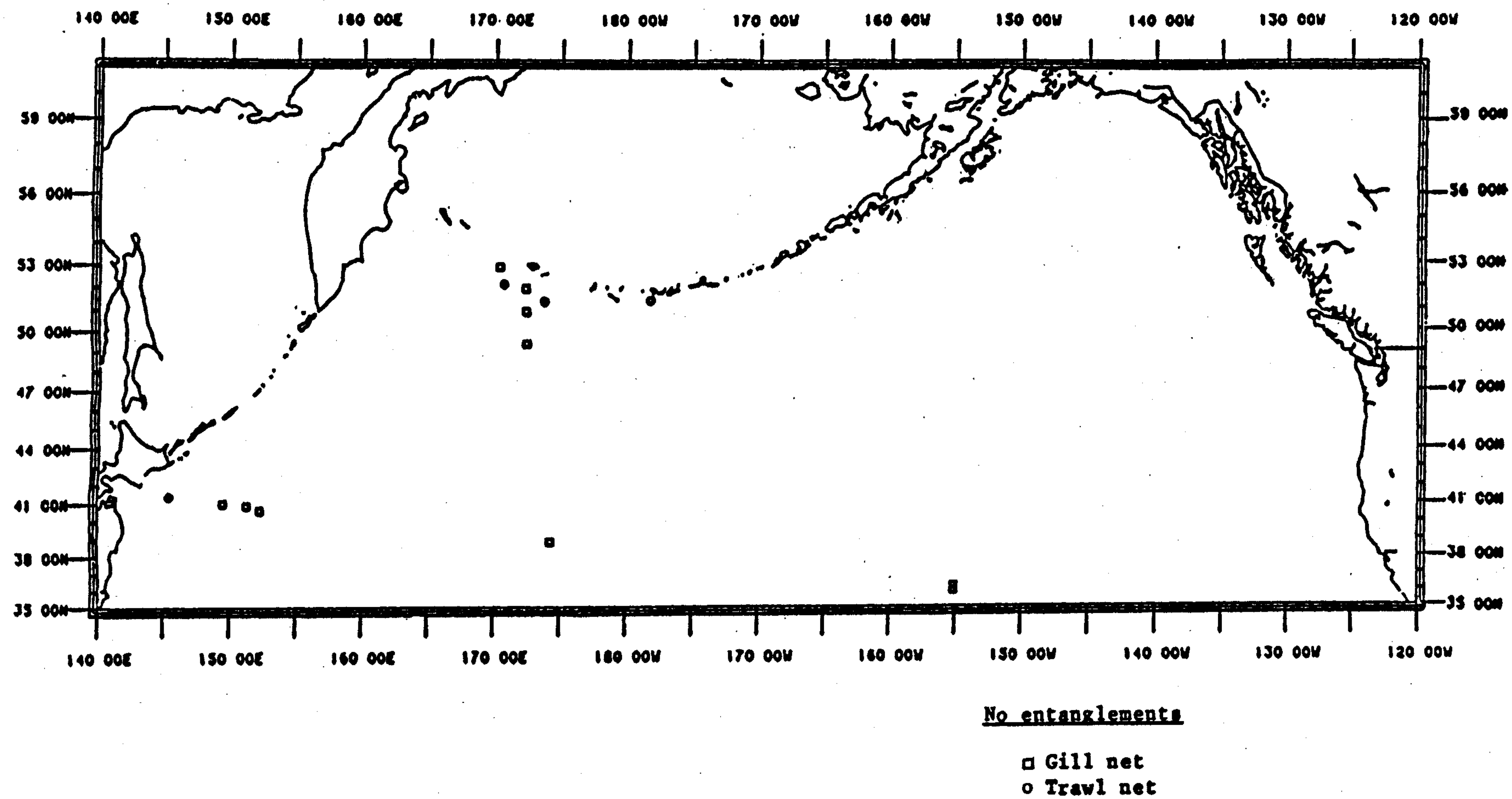
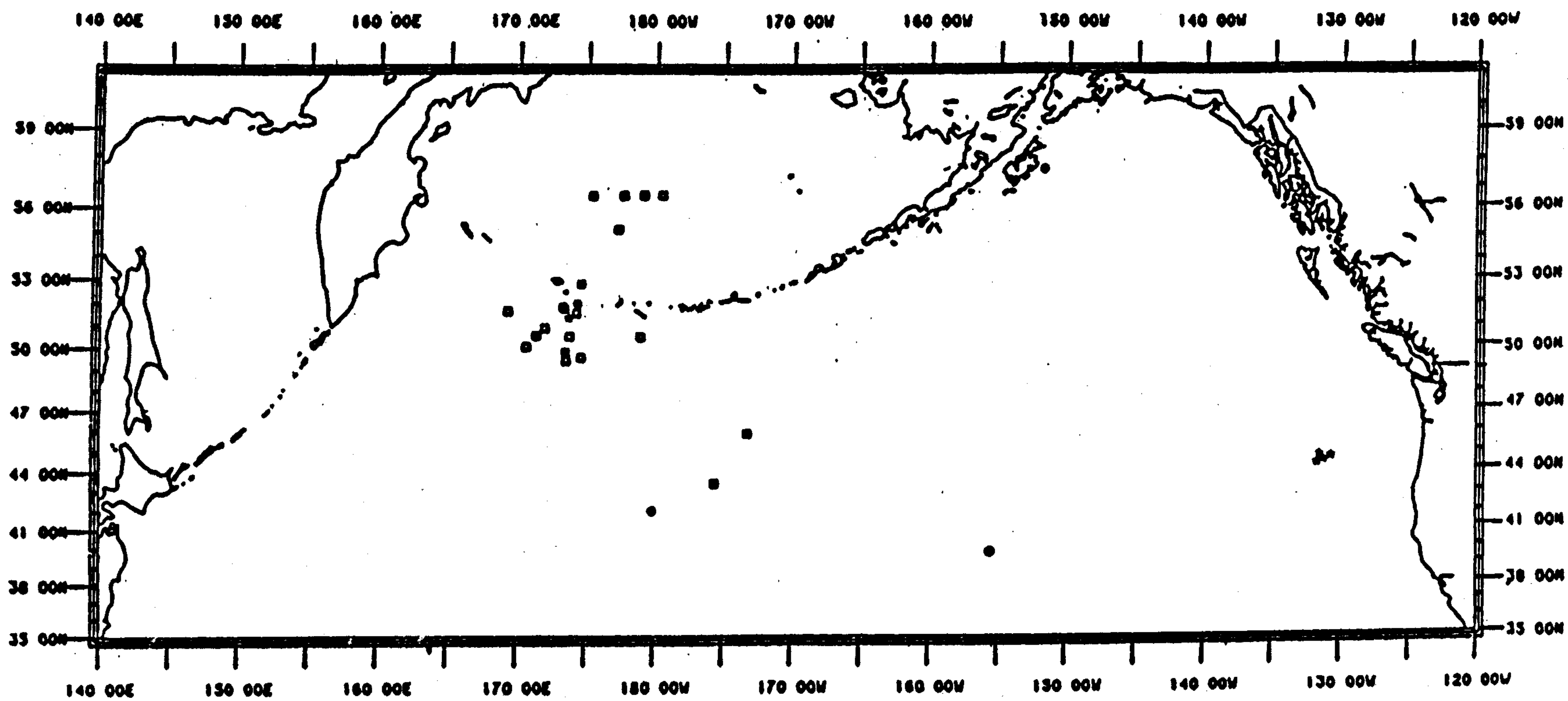


Figure 2.--Sighting of net debris during "on-effort" searches.

Table 2.--Sightings of net debris during "on-effort" searches by observers. See Table 1 for hours of sighting effort.

Date	Vessel type	Lat. N	Long.	Net type	Debris size	Entangle-ments
7/24/82	Research	38°28'	174°28'E	Gill net	20 m or more	None
6/20/83	Commercial	52°07'	170°35'E	Trawl	1 m or more	None
6/6/84	Commercial	51°16'	178°17'W	Trawl with yellow poly line	1 m^2	None
6/30/84	Commercial	50°58'	172°24'E	Gill net with floats	4 m	Kelp
7/19/84	Commercial	51°11'	173°40'E	Trawl, possibly broiler or sling	2 m^2	None
7/5/84	Research	40°59'	149°17'E	Gill net with floats	100-150 m	None
7/6/84	Research	52°52'	170°23'E	Gill net	Unknown	None
7/9/84	Research	51°55'	172°14'E	Gill net with floats	Unknown	None
7/12/84	Research	49°32'	172°37'E	Gill net	1 m^2	None
7/31/84	Research	36°01'	155°02'W	Gill net with floats	50 cm^3	None
7/31/84	Research	36°07'	155°02'W	Gill net with poly line	1 m	None
8/20/84	Research	40°47'	152°15'E	Gill net with floats	3 m	None
8/20/84	Research	40°55'	151°11'E	Gill net with floats	50 m	None
8/21/84	Research	41°18'	145°18'E	Trawl with 10 in. round, orange float	2 m	None



<u>No entanglements</u>

□ Gill net
○ Trawl net

<u>With entanglements</u>

■ Gill net
● Trawl net

<u>Other sightings</u>

* With fishing debris

Figure 3.--Sightings of net debris during "off-effort" searches.

The majority of net debris sightings were gill net fragments in the western North Pacific (Table 3). Of seven sightings in the eastern North Pacific, one trawl fragment, two gill net fragments, and four unidentified fragments were recorded. In the Bering Sea, there were six fragments; one was trawl net, the remainder, gill net (Table 3 and Fig. 3). The preponderance of gill net fragments is a reflection of sighting effort being mainly in gill net fishing areas.

The effect of weather conditions on sighting of debris is shown in Table 1. There were no "on-effort" sightings of net debris in sea state of Beaufort 4 or greater although there were 309+ h of observation. During "off-effort" periods, net fragments were sighted on nine occasions in sea states of Beaufort 4 or greater, however, in five cases the fragment was entangled in the vessel's gill net or other gear being brought on board (i.e., fragments were not sighted free floating).

In 7 years there were eight records of gill net discard from vessels. Corklines and leadlines were removed in all but one case. Size ranged from a clump of net <0.5 m^2 to a 400 m length.

Since 1978, three lost or abandoned gill nets have been sighted. In 1978 DeGange and Newby (1980), aboard a salmon research vessel in the western North Pacific (lat. 49°15'N and long. 168°14'E), observed the retrieval of 1,500 m of gill net with 99 seabirds, 2 salmon shark, <u>Lamna ditropis</u>, 1 ragfish, <u>Icosteus aenigmaticus</u>, and more than 200 chum salmon, <u>Oncorhynchus keta</u>, and coho salmon, <u>O. kisutch</u> entangled. On 16 June 1981, an abandoned gill net (approximately 15 km) was retrieved off Agattu Island (lat. 51°38'N and long. 175°48'E) by the crew of a vessel dedicated to marine mammal research. No marine mammals were entangled but there were two salmon shark, <u>L. ditropis</u>. At least 255 auklets (several species), 14 horned puffin, <u>Fratercula corniculata</u>, 37 tufted puffin, <u>Lunda cirrhata</u>, 16 murres, <u>Uria</u> spp., 17 shearwaters, <u>Puffinus</u> spp., and 14 unidentified birds were also entangled. Salmon were in poor condition indicating the net had been fishing for at least several days. Salmon were counted for only 35 min of the nearly 3 h of the retrieval period; the minimum observed count was 175.

On 15 July 1984 at lat. 55°18'N and long. 174°20'E, one section of gill net (approximately 5 km) including radar, radio, and light buoys was lost during fishing operations. Two sections (approximately 10 km) were retrieved, with one Dall's porpoise, <u>Phocoenoides dalli</u>, one ancient murrelet, <u>Synthliboramphus antiquus</u>, two spiny dogfish, <u>Squalus acanthias</u>, and numerous salmon.

DISCUSSION

The amount of net debris and number of associated entanglements observed are low in spite of the fact the study was conducted primarily in the gill net fishing area. The low incidence of sightings may be a function of the difficulty of sighting debris or of infrequent occurrence of net fragments. Certainly fragments are difficult to see if weather conditions are poor or the distance from the vessel is large. Although the majority of our sightings involved spotting floats on the fragments, the floats are small, often drab colored, and therefore, often difficult to see

Table 3.--Locations and types of net debris collected during poor sighting conditions, fishing operations, and other periods of nonactive search for net debris ("off-effort").

Date	Vessel type	Lat. N	Long.	Net debris: Type	Net debris: Size	Entanglements
			A. Western North Pacific Ocean			
6/14/84	Commercial	50°44'	171°49'E	Gill net and trawl with floats	1-1.5 m ball	Kelp
6/24/84	Commercial	49°29'	173°35'E	Gill net with floats	5 m	None
6/26/84	Commercial	52°07'	174°34'E	Trawl	4 m^2	None
6/27/84	Commercial	51°46'	174°25'E	Gill net with floats	10 m	None
7/1/84	Commercial	49°57'	173°38'E	Gill net with floats	2 m	Salmon shark
7/3/84	Commercial	51°44'	174°12'E	Gill net with blue floats	10 m	None
7/4/84	Research	51°45'	169°28'E	Gill net	0.2 m^2	
7/12/84	Research	50°41'	173°51'E	Gill net	1 m^2	None
7/13/84	Commercial	51°33'	174°03'E	Float with black webbing	Unknown	None
7/14/84	Commercial	56°35'	179°05'W	Gill net, 3-5 floats		None
7/15/84	Commercial	51°55'	173°35'E	Gill net	1 m^2	None
7/15/84	Commercial	51°55'	173°35'E	Gill net, black	2 m^2	None
7/16/84	Commercial	50°40'	179°03'E	Gill net	3 m^2	None
7/18/84	Commercial	49°44'	174°47'E	Gill net	0.5 m^2 clump	Kelp
6/27/83	Commercial	52°51'	174°50'E	Gill net	100 m or more	Salmon, 11 birds
7/9/83	Commercial	50°59'	172°06'E	Gill net	20.3-cm ball	None
6/19/82	Commercial	50°16'	170°47'E	Gill net (?)	Small piece around animal's neck	Northern fur seal
6/20/81	Research	42°22'	180°00	Trawl (?)	Unknown	2 northern fur seals
			B. Eastern North Pacific Ocean			
6/4/84	Research	44°40'	130°23'W	Net with glass ball	Unknown	None
6/6/84	Research	44°39°	130°27'W	Unknown	2 m clump	None (entangled on CTD gear)
6/6/84	Research	44°37'	130°27'W	Net with yellow glass ball	Unknown	None
6/7/84	Research	44°44'	130°38'W	Net with yellow glass ball	Unknown	None
7/29/84	Research	39°27'	155°00'W	Trawl	0.5 x 2 m	None
7/13/78	Research	45°49'	172°59'W	Gill net	Unknown	1 northern fur seal
7/17/78	Research	43°30'	175°00'W	Gill net	200 m	Unknown
			C. Bering Sea			
6/30/84	Commercial	57°05'	177°43'E	Gill net	2 m clump	Kelp
7/13/84	Commercial	56°30'	179°21'E	Gill net	0.5 m^2 clump	Algae
7/12/84	Commercial	56°29'	177°52'E	Gill net with floats	Small amount	None
7/13/84	Commercial	56°40'	178°08'E	Gill net	5 m	None
7/16/84	Commercial	56°34'	175°39'E	Gill net with floats	5 + 1-2 m trailing	None
7/9/80	Research	57°31'	151°28'W	Trawl (?)	Unknown	1 northern fur seal

unless close by and weather and sea state conditions are good. Since gill net monofilament is nearly transparent in water, to date gill net debris without floats attached have only been recorded when they entangle on operational gear. Thus, our sightings of net debris may underestimate the amount present in this area.

Observations of the discard or loss of gill nets from research and commercial vessels have been rare. The economic incentive from selling used nets for recycling in Japan may help to reduce the amount of discard (K. Kasai, 6-2 Otemachi 2-Chome, Chiyoda-ku, Tokyo, Japan to M. Dahlberg, Auke Bay Lab., Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Auke Bay, AK 99821 pers. commun., July 1983).

Movements of live animals entangled in debris may attract an observer's attention and increase the likelihood of sighting. However, dead animals are often submerged and thereby missed by the observers, possibly resulting in an underestimate of the number of entangled animals killed.

The lack of observations of cetacean entanglement in net fragments may be related to the low probability of entanglement. In the Japanese mother ship salmon fishery, entanglement of porpoise is a relatively rare event, even in the large commercial nets 15 km long (less than one porpoise per set) (Jones 1984). Therefore, the probability of an animal being caught in a small fragment would also be expected to be low.

All our sightings of marine mammals entangled in debris were of northern fur seals. Although entanglement in gill nets is rare in the salmon fishery (<10 per year), fur seals are frequently observed playing near the nets. It is possible they similarly play with fragments and become entangled if the mesh and fragment size are large enough.

Determining the impact of net debris on marine animal populations will require more information on a number of factors: Distribution of animals in relation to fishing operations, size of mesh, size of fragments, and the fate of debris in relation to ocean currents carrying the debris from its original location. For example, one gill net (5 km long) became tangled into a "green rope" within 24 h during a severe storm (Jones pers. observ.). Surf action may tangle net debris similarly (Merrill 1977:fig. 1; photograph in Anonymous 1973). These actions will reduce potential adverse impact on marine animals. Data are also needed on the relationship between fragment and mesh sizes and catchability of different species.

FUTURE RESEARCH

United States biologists on Japanese commercial and research vessels will continue to collect data on net debris and associated entanglements in 1985 and 1986. Observations of net debris will also be recorded by the National Oceanic and Atmospheric Administration research vessels operating in the eastern North Pacific and Bering Sea.

ACKNOWLEDGMENTS

The authors would like to thank the biologists aboard research and commercial vessels for collecting data and M. L. Dahlberg for generously providing his. We also thank Fisheries Agency of Japan and Federation of Japan Salmon Fisheries Cooperative for their support of this project. In addition, we thank H. W. Braham, M. L. Dahlberg, C. W. Fowler, R. V. Miller, M. K. Nerini, and R. Pearson for reviewing earlier drafts and contributing helpful comments. Finally, our thanks to L. Hietala and C. Bouchet for their assistance in preparation of the manuscript.

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ACCUMULATION OF NET FRAGMENTS AND OTHER MARINE DEBRIS IN THE NORTHWESTERN HAWAIIAN ISLANDS (Abstract only)

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ABSTRACT

Since 1982 Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, field personnel in the Northwestern Hawaiian Islands have monitored the presence and accumulation of webbing and other marine debris considered to pose a hazard to Hawaiian monk seals. This paper summarizes results of this effort in 1982 and 1983. Webbing samples have been grouped by twine diameter and mesh size and provisionally identified as to gear type. Rates of accumulation of marine debris are presented for Lisianski and Laysan Islands.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

OBSERVATIONS OF MAN-MADE OBJECTS ON THE SURFACE OF THE NORTH PACIFIC OCEAN

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ABSTRACT

Studies in the late 1970's of seabirds feeding on plastic and observations of the entanglement of marine mammals in man-made objects at sea have led to concern over the amount of debris accumulating in world oceans. In July and August of 1984, on the Japanese fisheries training vessel Oshoro Maru, a log was kept of man-made objects observed while transiting west from Cape Spencer, Alaska, along lat. 55°N until reaching long. 155°W and then traveling south to Honolulu, Hawaii; a second leg from Honolulu to Hakodate, Japan, was transited in mid-August of 1984. Sightings of 206 items were made between 13 July and 4 August during 124 h and 51 min of viewing while the ship traveled 2,917 nmi. Most (79%) of the debris items were seen between lat. 31° and 39°N along long. 155°W, an area of surface convergence. Only three sightings of net debris were made, and no animals were observed entangled in or near the small pieces of webbing. On the second transect from Hawaii to Hokkaido, Japan, 521 objects were seen between 12 and 21 August during 74 h and 10 min of viewing while the ship traveled 2,573 nmi. The highest density of material was seen between lat. 30° and 35°N. One small piece of gill net and one piece of unidentified webbing were seen. Again, no animals were observed entangled in the netting.

INTRODUCTION

The abundance of marine litter, especially plastic materials, has reached staggering proportions. Hundreds of millions of pounds of debris are being dumped into the sea each year; later, unknown portions of this debris appear on beaches, some of which are far from centers of human

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population (Merrell 1980). Limited observations of marine debris in the central North Pacific Ocean during 1972 indicated that litter on the sea surface is not limited to the vicinity of shipping lanes (Venrick et al. 1973). The concern over marine debris is relatively new, and scientific knowledge about the fate and impact of marine debris is just developing. Little is known about the source, amount, and impact of this debris, and virtually nothing is known about the dynamics of marine debris distribution and disappearance.

In the present study, observations on marine debris were systematically observed during routine sighting surveys for marine mammals and marine birds conducted aboard a Japanese training vessel (TV) in July and August 1984. The summer cruise of 1984 was the maiden voyage across the North Pacific Ocean by the TV Oshoro Maru, which is operated by the Faculty of Fisheries, Hokkaido University, Hakodate, Japan. After a port call at Juneau, Alaska, a cruise track was followed to sample stations with oceanographic instruments, small mesh nets, and pelagic gill nets en route to Honolulu, Hawaii, mainly along long. 155°W (Fig. 1), and then back to Hokkaido--point of origin. A log of marine debris observed was maintained between stations while the vessel was underway.

SURVEY METHODS

Observations were made from either the bridge (8 m above the water) or the flying bridge (10 m above the water) while the vessel was traveling between stations or during the setting of gill nets. Items were usually sighted while scanning abeam and ahead of the vessel. Either 8 x 32 or 10 x 40 binoculars were used to identify and estimate the size of each item. For each sighting, the distance from the observer to the item and the azimuth from the ship's heading to the item also were estimated and recorded with the time of sighting. Geographic coordinates and weather conditions were observed on the ship's satellite navigation system and recorded on the hour and half hour. At the end of the cruise, a formula for dead-reckoning was used to estimate the geographic coordinates of each object sighted from the time of day and half-hourly navigational positions. The items observed were classified by date and time observed, geographic coordinates, distance and angle of sighting, and type, description, and estimated size of material. No object was placed in more than one classification.

RESULTS

Sighting Survey Effort

Sighting surveys were conducted during 32 days while the ship transited approximately 34 degrees of latitude, mostly along long. 155°W (Fig. 1). Observations on the Alaska-Hawaii transect commenced at lat. 55°01.8'N, long. 140°01.2'W, and terminated at the Diamond Head Lighthouse (lat. 21°15.5'N, long. 157°48.7'W), a distance of 2,587 nmi of which 1,516 nmi (59%) were surveyed. Survey effort averaged about 5.5 h per day, and about 82% of the survey time was spent in sea-surface conditions of Beaufort scale 4 or less (Table 1). During 16 of the 23 days, drift gill nets were fished overnight along long. 155°W while the vessel drifted a short distance; therefore, most (75%) of the cruise track along long. 155°W

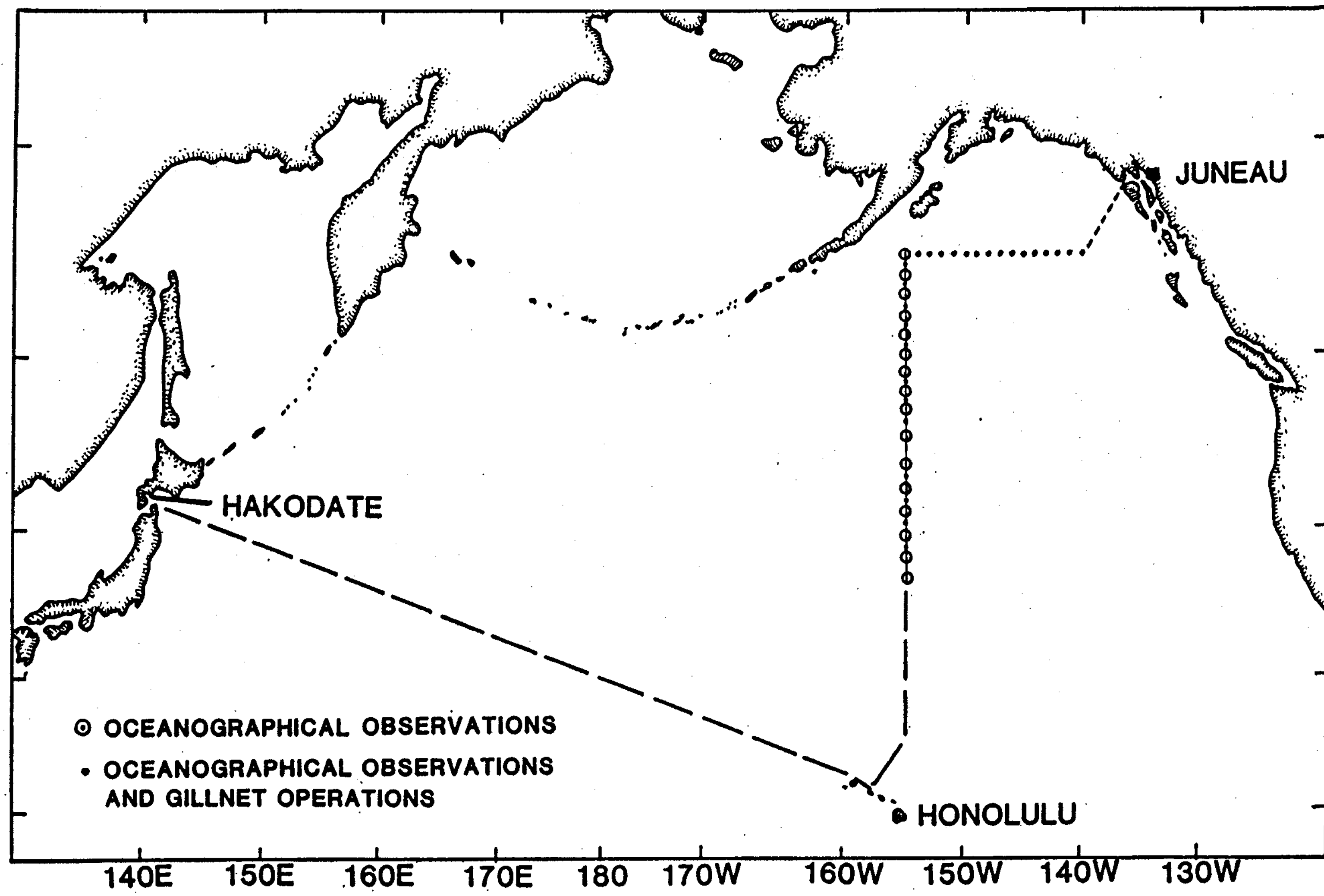


Figure 1.--Cruise track of TV Oshoro Maru, Alaska-Hawaii and Hawaii-Japan, July-August 1984.

Table 1.--Sighting survey effort (in hours and minutes) by sea surface conditions during the Alaska-Hawaii (13 July to 4 August 1984) and Hawaii-Japan (12-21 August 1984) transects.

Date 1984	Beaufort scale No. 1	2	3	4	5	6	Total
				ALASKA-HAWAII			
7/13		3:12					3:12
7/14	1:55	1:06	3:28				6:29
7/15		4:40	1:35				6:15
7/16			1:41	1:11			2:52
7/17			2:40	1:51			4:31
7/18		1:16	1:54				3:10
7/19		3:00	1:23	0:55			5:18
7/20					1:01	2:54	3:55
7/21			0:30		3:31		4:01
7/22			0:30	4:39			5:09
7/23		1:20	2:28				3:48
7/24	0:25	5:10					5:35
7/25		2:58	0:34	3:06			6:38
7/26			3:14	2:48			6:02
7/27			6:36				6:36
7/28		2:59	3:35				6:34
7/29	2:50	2:54					5:44
7/30			1:27	3:42			5:09
7/31			6:42				6:42
8/1		4:19	1:30				5:49
8/2					7:39		7:39
8/3					8:00		8:00
8/4				5:43			5:43
				HAWAII-JAPAN			
8/12		2:10	4:40	3:20			10:10
8/13	4:40	3:30					8:10
8/14		2:00	8:00				10:00
8/16			0:40	6:20	1:40		8:40
8/17		0:40	0:40	1:40	5:00	0:30	8:30
8/18	0:30	4:00	4:00	0:20			8:50
8/19				5:00	1:30		6:30
8/20		3:00	2:30	1:40			7:10
8/21	0:30	0:50	4:50				6:10
Total time	10:50	46:04	65:37	43:05	30:01	3:24	199:01
Percent	5.4	23.1	33.0	21.6	15.1	1.7	
Cumulative percent	5.4	28.5	61.5	83.1	98.2	99.9	

was observed during daylight. Only 6 of the 35 one-degree parallels of latitude were not observed due to the ship's transiting these parallels during darkness (Table 2). During the transect from Hawaii to Japan, observations began at lat. 27°16.5'N, long. 166°53.4'W on 12 August and terminated at lat. 41°33.7'N, long. 143°15.2'E on 21 August. Survey effort totaled 953 nmi (37%) during the transect of 2,573 nmi, which was covered in 10 days. Since the vessel was running continuously, latitudes transited during darkness were not sampled on the second transect. During this transect line, survey effort averaged about 8.5 h per day, and about 86% of the survey time was spent in sea-surface conditions of Beaufort scale 4 or less (Table 1).

Objects Observed

The objects recorded were tabulated by various classifications, e.g., description and type of material, distance and angle observed, latitudinal band, and time of day observed. Most (80%) of the 727 objects were either foamed or structural plastic in the form of fishing floats, irregularly sized sheets, or fragments (Fig. 2, Table 2). Glass (bottles and floats), wood (logs and lumber), and paper (mostly cardboard) constituted a secondary group of materials, whereas metal and cloth items were rarely seen. Only three small pieces (two gill nets, one trawl) of netting and four lengths of synthetic rope were seen on the first transect. The latitudinal distribution of items observed showed striking peaks in the number of objects observed and the relative incidence (objects observed per nautical mile surveyed) between lat. 40° and 29°N (Fig. 3, Table 3). Only one object was seen between lat. 49° and 43°N, although 23% of the survey miles of effort was spent in that portion of the cruise track. Distance at which objects were first sighted seemed to be related to their size, color, shape, and buoyancy; even small white fragments of styrofoam were seen as far away as 100 m, whereas small clear sheets of plastic were never seen farther than 75 m away (Fig. 4). Since sighting effort was concentrated forward in approximately a 180° arc from the starboard beam to the port beam, few objects (4%) were seen abaft. Nearly twice as many objects were seen to starboard compared with port, because sighting effort from the bridge was done on the starboard side so as not to interfere with the watch officers. The time of day objects were observed was directly related to survey effort during the day. Most of the survey effort (81%) was between 0800 and 1600, during which time 88% of the objects were seen. The discrepancy in composition between effort and objects observed was due to more effort (8%) being expended over the time period 1900-2000 when gill nets were being set at slow speed; few objects (2%) were seen during this time because of decreased distance traveled and crepuscular lighting conditions.

There were two main concentrations of marine debris on the Alaska-Hawaii survey, one at lat. 50°-52°N and one at lat. 31°-39°N (Fig. 3). The first concentration roughly coincides with a small zone of surface downwelling in the area lat. 51°-54°N (unpublished CTD data from TV Oshoro Maru, courtesy of Faculty of Fisheries, Hokkaido University, Hakodata, Japan); this surface downwelling may be part of a small-scale eddy generated by seamounts in this region (Royer 1978; Shaw and Mapes 1979). The second, larger concentration of debris was in a zone of surface convergence caused by converging Ekman transports between lat. 28° and 42°N

Table 2.--Description of objects observed adrift on the surface of the North Pacific Ocean, July-August 1984.

Description	No. of occurrences
Bag	9
Ball	3
Bamboo	2
Basket	4
Board	4
Bottle	85
Bowl	1
Box	10
Bucket	9
Bucket lid	1
Can	2
Cap	5
Cardboard	1
Carton	3
Cloth	1
Crate	6
Cup	9
Dish	1
Disk	5
Drum	1
Float	58
Fluorescent lamp	4
Fragment	309
Gill net	3
Gill net float	23
Helmet	1
Incandescent lamp	5
Jar	5
Lid	2
Line	18
Log	12
Magazine	1
Matting	1
Netting	1
Pallet	1
Pan	3
Ring	3
Sandal	1
Screen	1
Sheeting	94
Shoe insole	1
Shovel	1
Sponge	3
Strap	1
Trawl float	6
Trawl webbing	1
Tray	5
Tube	1
Total	727

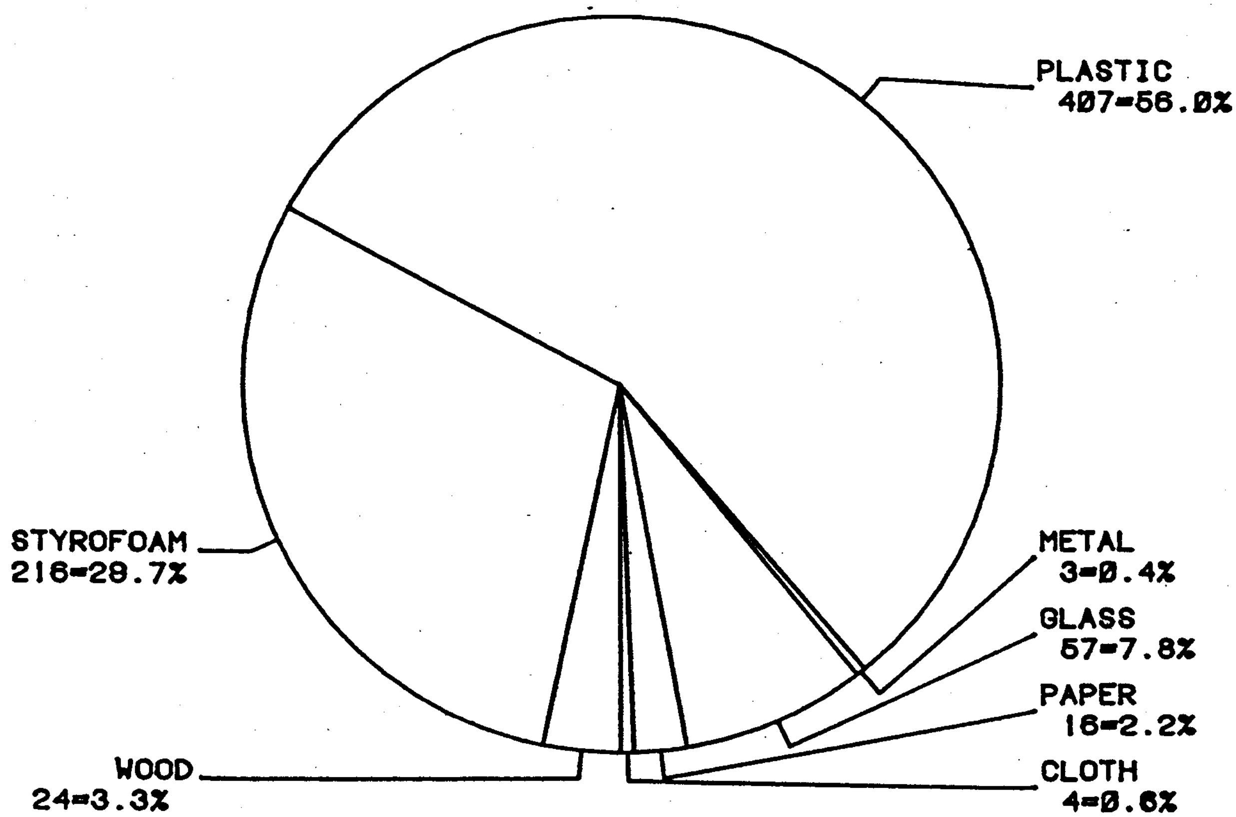
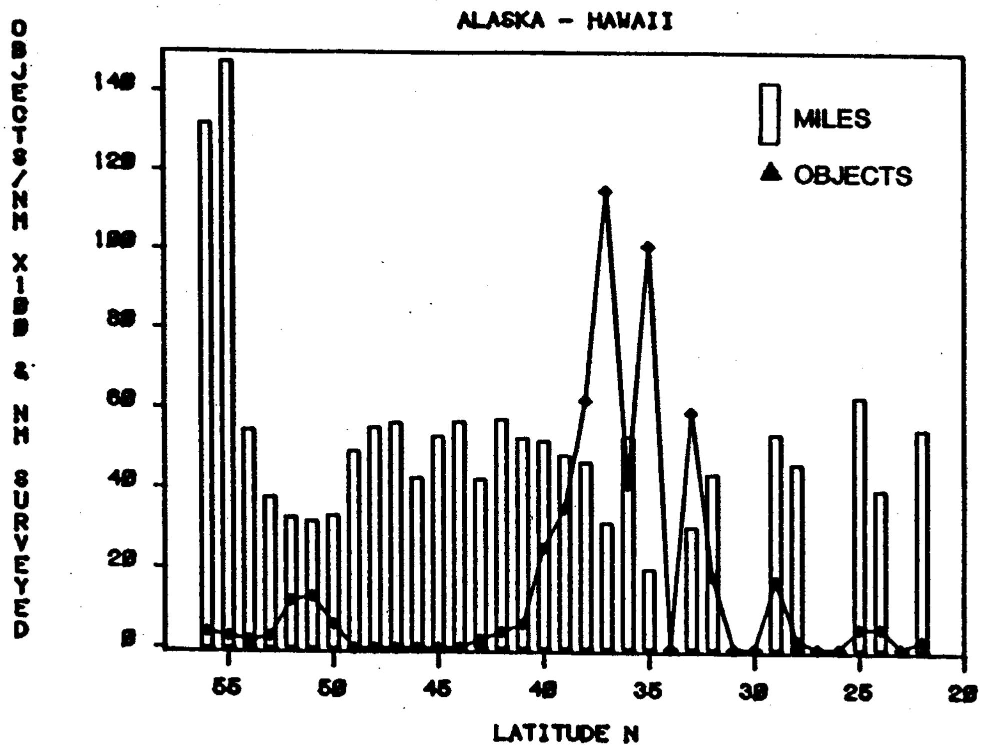


Figure 2.--Approximate composition of a sample of objects sighted on the surface of the North Pacific Ocean, July-August 1984.



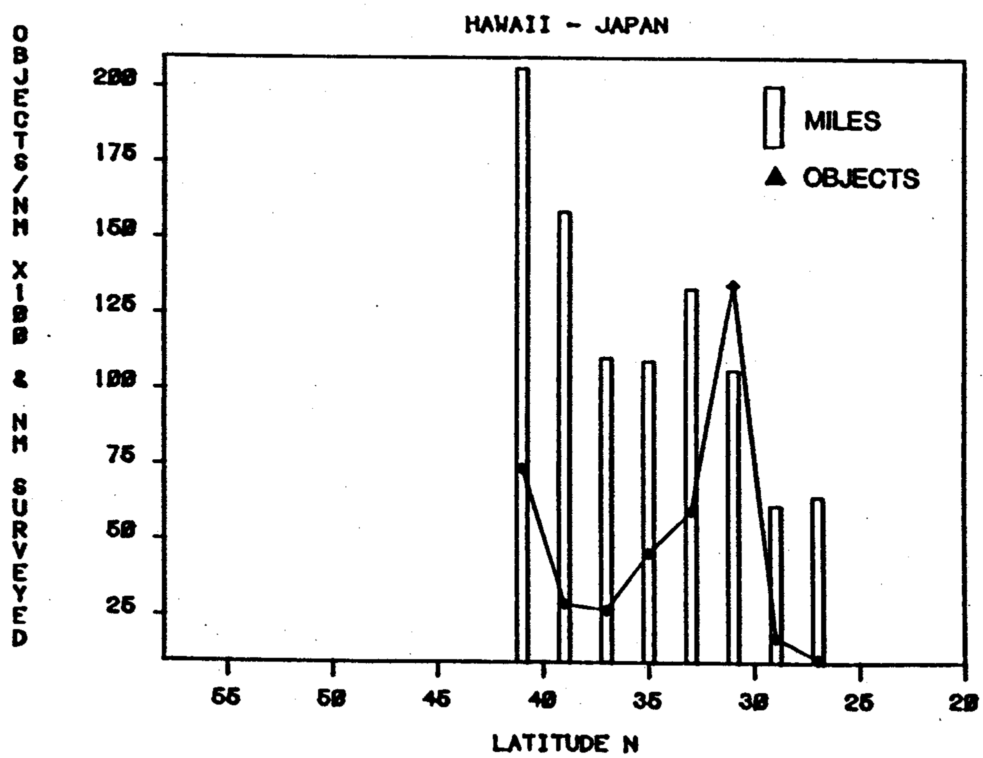


Figure 3.--Latitudinal distribution of nautical miles of sighting survey effort (bars) and objects observed per nautical mile surveyed (solid line).

Table 3.--Latitudinal distribution of the distance and area surveyed and the estimated density of objects and the density of plastic observed on the surface of the North Pacific Ocean in July-August 1984.

Lat. (°N)	Distance surveyed (nmi)	Area surveyed[2] (km^2)	Total No. of objects observed		No. of objects seen 0-50 m from ship	Density of objects[1] (No. per km^2)	No. of plastic objects seen 0-50 m from ship	Density of plastic objects (No. per km^2)
			No.	Objects per nmi x 100				
				ALASKA-HAWAII				
55-56	131.9	12.1	5	4	1	0.08	0	0
54-55	147.5	13.5	4	3	1	0.07	0	0
53-54	54.5	5.0	1	2	1	0.20	0	0
52-53	37.7	3.5	1	3	1	0.29	0	0
51-52	32.7	3.0	4	12	3	1.00	1	0.33
50-51	31.8	2.9	4	13	3	1.03	2	0.69
49-50	33.1	3.0	2	6	2	0.67	0	0
48-49	49.2	4.5	0	0	0	0	0	0
47-48	55.2	5.1	0	0	0	0	0	0
46-47	56.3	5.2	0	0	0	0	0	0
45-46	42.5	3.9	0	0	0	0	0	0
44-45	53.0	4.9	0	0	0	0	0	0
43-44	56.6	5.2	0	0	0	0	0	0
42-43	42.2	3.9	1	2	1	0.26	0	0
41-42	57.2	5.3	2	4	2	0.38	1	0.19
40-41	52.5	4.9	3	6	3	0.63	3	0.63
39-40	51.8	4.8	13	25	7	1.46	7	1.46
38-39	48.2	4.4	17	35	8	1.82	3	0.68
37-38	46.5	4.3	29	62	18	4.19	17	3.95
36-37	31.4	2.9	36	115	23	7.93	20	6.90
35-36	53.0	4.9	22	41	14	2.86	13	2.65
34-35	19.8	1.8	20	101	6	3.33	4	2.22
33-34	0	0	--	--	--	--	--	--
32-33	30.4	2.8	18	59	12	4.29	7	2.50
31-32	43.5	4.0	8	18	6	1.50	4	1.00
30-31	0	0	--	--	--	--	--	--
29-30	0	0	--	--	--	--	--	--

Table 3.--Continued.

Lat. (°N)	Distance surveyed (nmi)	Area surveyed[2] (km^2)	Total No. of objects observed: No.	Total No. of objects observed: Objects per nmi x 100	No. of objects seen 0-50 m from ship	Density of objects[1] (No. per km^2)	No. of plastic objects seen 0-50 m from ship	Density of plastic objects (No. per km^2)
28-29	53.6	4.9	9	17	4	0.82	4	0.82
27-28	46.1	4.2	1	2	0	0	0	0
26-27	0	0	--	--	--	--	--	--
25-26	0	0	--	--	--	--	--	--
24-25	62.9	5.8	3	5	2	0.34	2	0.34
23-24	39.7	3.6	2	5	2	0.56	1	0.28
22-23	0	0	--	--	--	--	--	--
21-22	55.0	5.1	1	2	0	0	0	0
				HAWAII-JAPAN				
41-42	100.0	9.2	120	120	103	11.20	94	10.22
40-41	106.5	9.8	44	41	38	3.88	31	3.16
39-40	59.6	5.5	6	10	5	0.91	4	0.73
38-39	99.3	9.1	39	39	29	3.19	25	2.75
37-38	85.1	7.8	24	28	16	2.05	14	1.79
36-37	25.6	2.4	6	23	6	2.50	6	2.50
35-36	79.6	7.3	32	40	24	3.29	22	3.01
34-35	30.1	2.8	19	63	13	4.64	11	3.93
33-34	69.4	6.4	52	75	38	5.94	38	5.94
32-33	64.3	5.9	43	67	38	6.44	36	6.10
31-32	3.6	0.3	0	0	0	0	0	0
30-31	103.1	9.5	131	127	96	10.11	76	8.00
29-30	0	--	--	--	--	--	--	--
28-29	61.8	5.7	11	18	11	1.93	8	1.40
27-28	64.7	5.9	7	11	7	1.19	5	0.85

[1]Assuming all objects larger than 2.5 x 2.5 x 2.5 cm were seen within transect.
[2]Using a transect width of 50 m.

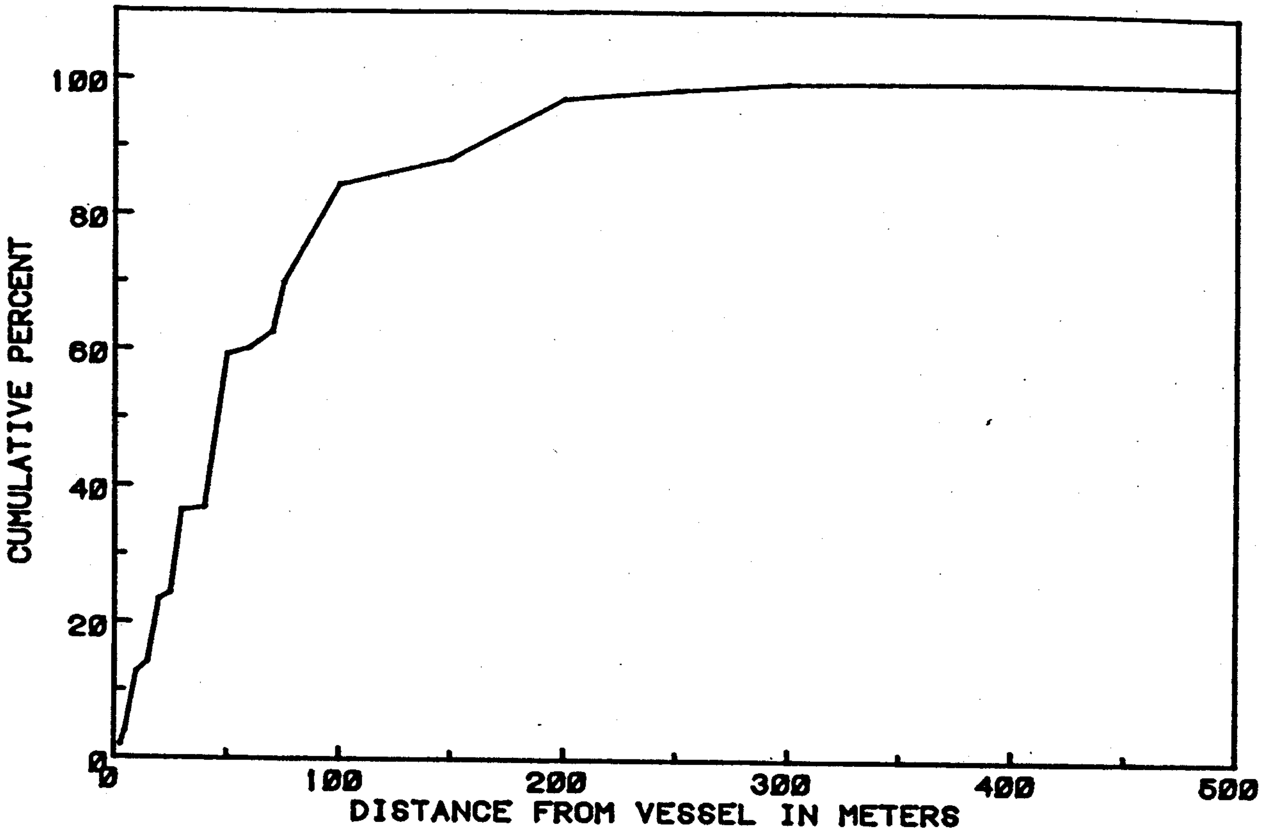


Figure 4.--Cumulative frequency distribution (%) of distance at which objects were first sighted from the vessel.

(Roden 1970). Shaw and Mapes (1979) also found plastic concentrations in the region of lat. 28°-38°N on a transect along long. 158°W, but found no plastic north of lat. 39°N.

There were also two main concentrations of marine debris on the Hawaii-Japan survey, one at lat. 30°-35°N and one at 41°-42°N (Table 2). The first concentration was again in the zone of converging Ekman transports (Roden 1970). The second concentration was in an area just east of Japan, which is an important source for marine debris in the western Pacific (e.g., see Merrell 1980).

On the evenings of July 31 and August 1 at lat. 34° and 31°N, respectively, small plastic pellets and fragments along with light-gauge thread, appeared in surface hauls of a surface ichthyoplankton net that was towed abeam the ship for 20 min per haul (Fig. 5). Plastic detritus did not appear in surface hauls at other stations between lat. 55° and 27°N. The band of surface water sampled by the circular net opening was approximately 20-30 cm, so very little area was swept by the gear, yet in several of four hauls on the above two nights, small pieces of plastic appeared floating in the pan used to sort catches immediately after the haul. The density of particulate plastics at the water surface must have been relatively high here for the net to have picked up much material (Shiber 1982; Gregory 1983).

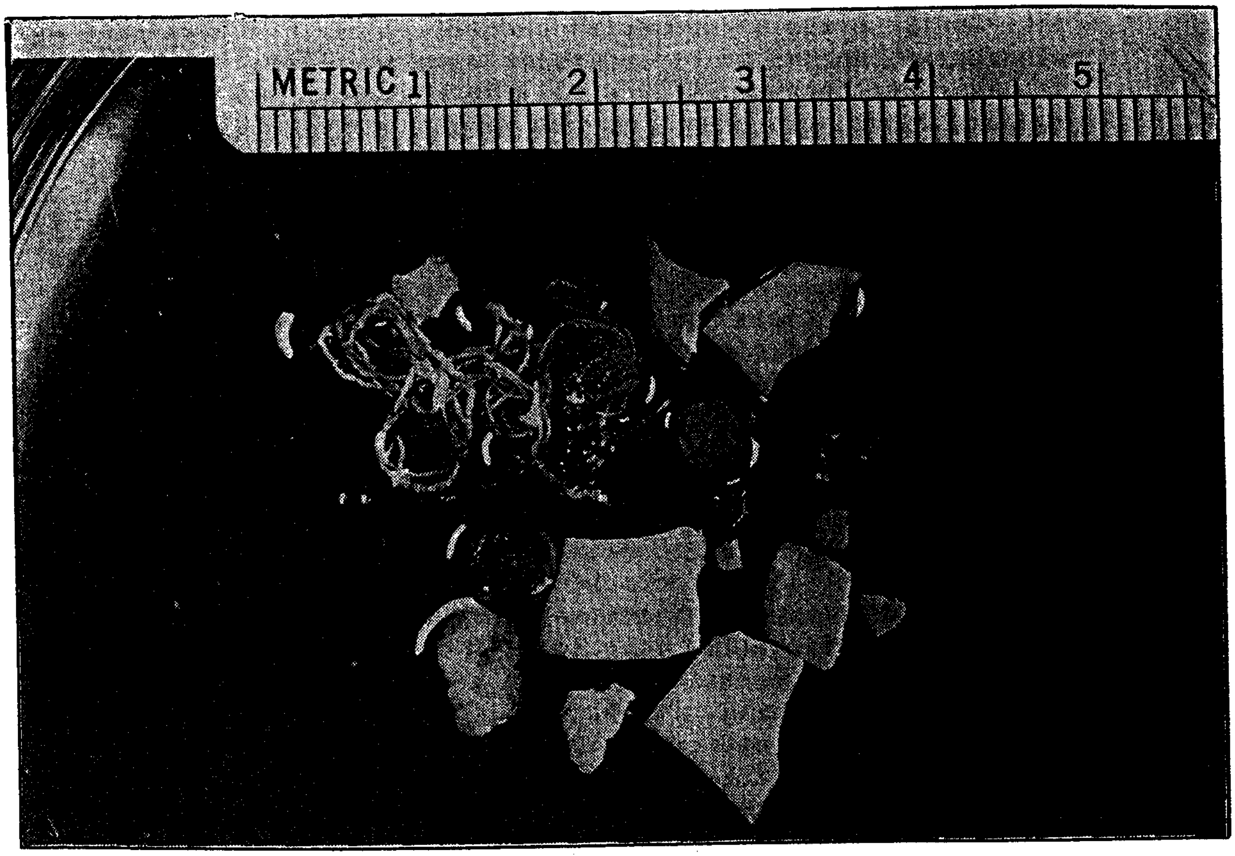


Figure 5.--Photo-micrograph of plastic debris caught in a surface haul of an ichthyoplankton net at lat. 31°N and long. 155°W.

DISCUSSION

The large proportion of plastic materials (86%) observed in this study is consistent with results of earlier studies of marine debris reported by Venrick et al. (1973) for the area between lat. 35° and 31°N and by Shaw and Mapes (1979) for a cruise between Alaska and Hawaii. Although Venrick et al. surveyed for debris for only 8.2 h, they saw 53 man-made objects, of which two-thirds were plastic. Plastic materials, rope, and twine constituted 60% of the frequency of occurrence of debris observed in trawl hauls in the Bering Sea during 1975 and 1976 (Feder et al. 1978). Plastic debris in general poses some problems to shipping (lines and nets foul propellers and plastic sheeting blocks seawater intake ports), but debris also has serious implications in animal mortalities (Coleman and Wehle 1984).

Entanglement of seabirds and marine mammals in derelict fishing nets and other man-made objects has been documented in several of the world's oceans (Tull et al. 1972; Shaughnessy 1980; Fowler 1982). Ingestion of marine debris, especially floating plastic, by seabirds also may cause mortality or decreased reproductive performance (Day 1980; Day et al. 1985). Northern fur seal, Callorhinus ursinus, were seen near the research gill nets during 7 of our 16 hauls in 1984. One fur seal escaped from the net as it was being hauled and one other was found dead in the net. Of 18 northern fur seals observed on 15 net-hauling occasions, none appeared entangled in any man-made objects. The low incidence of derelict fishing nets observed (<1% of all objects seen) and the fact that they were wrapped tightly in a ball may not make them available to entangling marine mammals.

Many of the objects we observed, especially the larger fishing gear floats, were heavily encrusted with fouling organisms, suggesting that the material had been adrift for a long time (Winston 1982). In addition, some of the plastic floats had faded considerably from international orange to a light pink, indicating long exposure. Determining the length of time marine debris is adrift may be possible through studies of marked gear released and monitored over a period of months or years with the aid of satellite tracking buoys coupled with periodic visits by vessels to observe and record the appearance of the gear.

Density estimates of debris were calculated keeping in mind the three significant problems associated with estimating at-sea densities of marine debris. First, paper objects are probably underrepresented due to sinking and rapid deterioration once this material is exposed to seawater. Second, the width of the transect surveyed is extremely difficult to define because of the large variation in the size of objects seen and their visibility due to distance, sea conditions, glare, color of the objects, and their buoyancy. Last of all, many objects sink and are never seen on censuses. Densities of marine debris in the study area were estimated, with four qualifications: (1) Estimates refer only to positively-buoyant debris (i.e., debris at the surface of the water); (2) estimates refer only to objects visible from the ship; the minimum size of objects sighted was approximately 2.5 cm^3; (3) density estimates were derived from only the inner 50 m of transect width; 59% of all objects were sighted in the inner 50 m of transect width, whereas only 24% were sighted in the next 50 m out from the ship (Fig. 4), indicating substantial fall-off of sightings; and (4) we assume that all objects larger than 2.5 cm^3 were seen within 50 m of the ship.

Using the above qualifications, we estimate that the average density of marine debris larger than approximately 2.5 cm^3 was 0.28 per km^2 in subarctic waters (lat. 39°-56°N) and 3.73 objects per km^2 in subtropical waters (lat. 21°-39°N in the Alaska-Hawaii surveys and lat. 27°-42°N in the Hawaii-Japan surveys). Densities of plastic averaged 0.15 objects per km^2 in subarctic waters and 3.15 objects per km^2 in subtropical waters (Table 3). For comparison with the data presented by Venrick et al. (1973), we estimated they saw an average of 4.24 pieces of marine debris per km^2, of which 2.24 pieces were plastic, in the subtropical North Pacific Ocean. Their observations were taken in the area lat. 31°-35°N, long. 145°-155°W, and were thus, in the zone of highest density of marine debris found 12 years later in our study. The only other comparable data are from the Mediterranean, where Morris (1980) found an average density of approximately 2,000 pieces of marine debris per km^2; 60-70% of this debris consisted of pieces of plastic. Although our estimates have several qualifications, they provide order-of-magnitude approximations of densities of medium-to-large pieces of plastic and other debris.

Quantifying the total amount of oceanic litter is difficult due to the wide variation in size, shape, and buoyancy of the material. Observations from ships may provide useful indices of the type and amount of debris, but beach surveys may be more useful and less costly in measuring the rate of loss of debris from the ocean. However, beach surveys would not reveal that debris lost from the surface by sinking. Beach surveys could also be used to test the predictions of surface transport models.

ACKNOWLEDGMENTS

We thank T. N. Merrell, M. C. Murphy, and D. G. Shaw for reviewing the manuscript and Susan Fowler, Mark Carls, and Elmer Landingham for the computer graphics, photography, and drafting work that the figures required. We are also grateful to the officers, crew, and cadets of the TV Oshoro Maru, especially Captain K. Masuda and H. Nakano.

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THEORETICAL FIRST APPROXIMATIONS OF DENSITIES OF DISCARDED WEBBING IN THE EASTERN NORTH PACIFIC OCEAN AND BERING SEA

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ABSTRACT

First approximations of densities of discarded webbing in the eastern North Pacific Ocean and Bering Sea are developed and discussed. The approximations are based on estimates of northern fur seal mortality rates, assumed distributions of webbing, and assumptions on fur seal behavior. The results are examined with respect to the design of sea surveys to determine the validity of the assumptions and estimate densities of discarded webbing.

INTRODUCTION

Part of the task of determining the effect of marine debris on marine mammals is to estimate the density and distribution of marine debris on the surface of the ocean. This is particularly true for the types of debris that appear to be causing problems with marine mammals. This study makes first approximations of densities of marine debris that appear to be causing high mortality rates for the northern fur seal, Callorhinus ursinus.

An analysis of available data by Fowler (1982) indicated that populations of northern fur seals are undergoing higher than expected mortalities and that discarded trawl webbing and perhaps plastic wrapping bands could be the cause of the unexplained high mortalities. Further investigation by Fowler (1984) and Fowler et al. (1985) supported the first study by Fowler (1982).

The studies presented data showing that about 64% of fur seals found with entangling debris on the Pribilof Islands were entangled in trawl webbing and about 22% were entangled in discarded plastic packing bands. Their work indicated that discarded trawl webbing is probably more important than implied by the above data because seals entangled in large pieces of webbing probably do not reach the Pribilofs. The data also indicated that only a small portion (8.5%) of trawl webbing that washed up on beaches is of the size that causes most entanglements (20-25 cm stretched mesh). Thus, it appears that only a small portion of marine debris may be responsible for the increased mortality.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

Fowler (1982, 1984, pers. commun., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98115-6349, August and October 1984) and Fowler et al. (in press) indicated that much of the mortality is occurring during the first 2 years of life. For example, between the time that male fur seal pups leave the Pribilof rookeries and return as subadults (20 months), survival is only 30% instead of an expected 50%.

If it is assumed that mortality rates are constant over the 20-month period, the estimate of instantaneous rate of total mortality (Z) without the effect of marine debris is

$$0.5 = \exp(-Z(20/232))$$

$$Z = -(\ln 0.5)/(20/12)$$

$$= 0.42 \quad .$$

This is also an estimate of the rate of natural mortality (M), because it is assumed that there are no nonnatural sources of mortality. The estimate of Z given the assumed effects of marine debris is

$$0.3 = \exp(-Z(20/12))$$

$$Z = -\ln(0.3)/(20/12)$$

$$= 0.72 \quad .$$

An estimate of the rate of mortality caused by marine debris (D) is given by

$$Z = D+M$$

$$D = 0.72 - 0.42$$

$$= 0.3 \quad .$$

The expectation of death caused by marine debris in 1 year (U) is given by

$$U = D(1-\exp(-Z))/Z$$

$$= 0.21 \quad .$$

The expectation of death caused by marine debris over the 20-month period is given by

$$U = D(1-\exp(-Z(20/12))/Z$$

$$= 0.29 \quad .$$

The literature (e.g., Kajimura 1984) indicates that male pups undergo one or two migrations between the Pribilofs and California during the 20 months at sea. Assuming that the animals travel along the coast line (most sightings are between 70 and 130 km of the coast) and don't deviate from their course, they travel between 5,400 and 10,800 nmi in the 20 months.

The migration appears to take about 2 months in each direction. Thus it appears that about 4 to 8 of the 20 months are spent migrating, and the remaining time is spent making local movements related to feeding and other activities. If it is assumed that similar distances are covered during nonmigrating months, the pups travel about 27,000 nmi during the 20 months at sea (1,350 nmi per month or about 45 nmi per day). This amount of travel seems high, particularly in view of evidence that not all male fur seal pups make the complete migration. It seems reasonable to use 27,000 nmi as an upper bound and 5,400 nmi as a lower bound.

Since we estimate that expectation of death from webbing encounters is 0.29 during the 20 months, it is reasonable to estimate fatal encounters per nautical mile (EPM) to be

$$\text{EPM} = 0.29/5{,}400 \text{ to } 0.29/27{,}000$$

$$= 0.000054 \text{ to } 0.000011$$

or in other words, there is one fatal encounter per 18,600–93,100 nmi of travel.

There are no data available on the searching path width of fur seals. If the animals are detecting webbing visually, searching path width is probably around 10 m (0.0054 nmi) on each side. On the other hand, if acoustics are being used it is not unreasonable to assume that a fur seal could detect a school of fish associated with discarded webbing 1,000 m (0.54 nmi) away. Thus, there appears to be one fatal encounter with webbing per 200 to 100,548 nmi^2 of searched water (geometric average 4,484 nmi^2).

How do these estimates fit in with what has been reported on observations from vessels? A paper presented at the workshop (Jones and Ferrero 1985) reported that four items of trawl webbing were found during 1,153 h of searching, while traveling 10,528 nmi in the North Pacific. There was one sighting per 2,633 nmi. It seems reasonable that an observer could detect pieces of webbing 100–200 m (0.054–0.108 nmi) on each side of the vessel. Thus, it appears that there was one sighting per 284–568 nmi^2 searched. If Fowler's (1982, 1984, pers. commun.) estimate that only 8.5% of discarded trawl webbing causes most mortality is correct, then there would be one unit of webbing of the dangerous mesh size per 3,342–6,683 nmi^2 (geometric average 4,726 nmi^2).

To compare the estimated density derived from observations with estimates derived from mortality rates, it is necessary to make more assumptions. First, it is necessary to make an assumption about the percentage of encounters between fur seals and webbing that are fatal. Second, it must be assumed that vessels and fur seals are searching areas that have similar densities of webbing. It should be noted that vessel observations were made west of the major fur seal migration area in the Gulf of Alaska. It seems likely that not all encounters are fatal. If this is true the estimated density of webbing derived from mortality rates is too low. It also seems likely that the seals would search in areas that contain higher than average densities of webbing, because factors that concentrate webbing may also concentrate food. In addition there probably is some communication between animals that would increase searching ability. Kajimura (1984) noted that fur seals at sea tend to be solitary except when feeding in areas containing food concentrations. These factors would tend to cause density estimates based on mortality to be too high. Perhaps violations of an assumption that all encounters are fatal and of the second assumption would cancel each other out, and I will assume that this is true. Under this assumption the two estimates of webbing density are similar.

The results of the first approximations indicate two things. First, the density of webbing appears to be quite low. Second, there appears to be enough discarded webbing to cause the estimated mortalities.

These two conclusions lead to further conclusions. First, if it is desired to maintain populations of northern fur seals, serious research should be conducted to verify that the problem is as serious as it appears to be. Second, preliminary efforts should be begun to reduce the apparent problem.

The low density of webbing indicates that it is not likely to be efficient to use dedicated vessels to either study the problem through surveys or solve the problem by cleaning up the ocean. Piggyback surveys probably should be continued and could be improved by better quantifying the techniques and working in areas preferred by fur seals. Modification of fishing gear and practices probably have the highest probability of solving the problem.

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FISHING EFFORT BY NET FISHERIES IN THE NORTH PACIFIC OCEAN AND BERING SEA SINCE THE 1950'S

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ABSTRACT

A synthesis of data on the amount of fishing effort generated by a number of net fisheries in the North Pacific Ocean and Bering Sea since the 1950's is presented here so as to provide background information relevant to studies of the fate and impact of marine debris in the North Pacific Ocean. It is estimated that total trawl fishing effort in the Bering Sea-Aleutian Islands-northeast Pacific Ocean more than tripled between 1956-60 and 1971-75. Currently, overall effort remains near the high level of the early 1970's, but trends have differed between areas and fisheries. Gill net effort by high seas salmon fisheries in the Bering Sea and central-western North Pacific Ocean currently is less than one-half of what it was in the late 1950's and early 1960's. A tangle net fishery for crabs in the southeastern Bering Sea was terminated in 1973, and a herring gill net fishery in the Bering Sea was terminated in 1980. Peak effort for both fisheries had been in the mid-1960's.

INTRODUCTION

The history of commercial exploitation of fishery resources in the North Pacific Ocean and adjacent seas goes back more than a century, but it has only been within the past 30 years or so that a number of major net fisheries have developed for various species of fish. These include trawl fisheries for groundfish in the eastern and central Bering Sea, around the Aleutian Islands, and in the northeast Pacific Ocean; gill net and trawl fisheries for herring in the Bering Sea; a tangle net fishery for crabs in southeastern Bering Sea; and drift net fisheries for salmon in the Bering Sea and central and western North Pacific Ocean. Scale of development and duration of the various fisheries are indicated in published reports of catch statistics, but data on the amount of fishing effort generated by those fisheries over the years are not readily available in the literature. A synthesis of such data is presented here to provide background information relevant to studies of the fate and impact of marine debris in the North Pacific Ocean.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

BERING SEA-ALEUTIAN ISLANDS REGION

Groundfish, Shrimp, and Herring Trawl Fisheries

Post-World War II fishing by foreign trawlers in the Bering Sea-Aleutian Islands region (Fig. 1) began in 1954 when Japanese vessels initiated a fishery for flatfish in waters east of long. 170°W. Fishing was largely exploratory in nature and limited in scale until 1959 when Soviet trawlers, after having conducted surveys of fishery resources in the region in 1954 and 1958, also started fishing for groundfish (and herring) on a commercial scale in the eastern Bering Sea. From that year through 1962, there was a marked increase in trawling by the two nations, judging from catches reported for Japanese and Soviet vessels, and information on the numbers of mother ship fleets and independent trawlers engaged in Japan's fishery (Forrester et al. 1978).

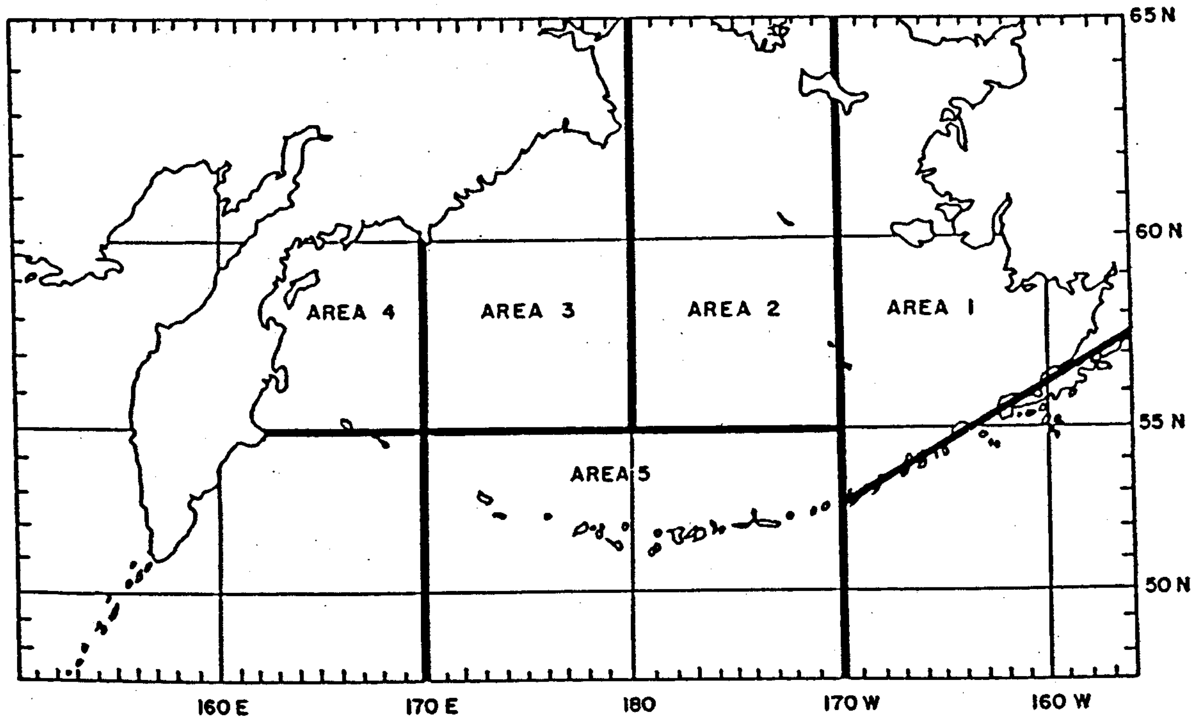

Figure 1.--The Bering Sea region as defined by the International North Pacific Fisheries Commission and its areal divisions.

Overall growth of the Japanese and Soviet trawl fisheries during 1954-62 is indicated by annual catches (in metric tons (MT)) of groundfish and herring (Forrester et al. 1978).

	Groundfish catch (1,000 MT)			Herring catch (1,000 MT)
Year	Japan	U.S.S.R	Total	U.S.S.R.
1954	13	--	13	--
1955	15	--	15	--
1956	25	--	25	--
1957	24	--	24	--
1958	46	5	51	--
1959	159	62	221	10
1960	435	96	531	10
1961	533	154	687	80
1962	476	140	616	150

Since 1963, Japan has reported not only the catches taken by the various types of trawlers used in its groundfish fishery but also the number of hours fished annually or, in the case of Danish seiners, the number of sets made, which can be converted to hours of fishing (Appendix Table 1A). Hours of fishing by Japanese shrimp trawlers have also been reported for each year of operation since 1963.

Fishing effort by Soviet groundfish trawlers during 1963-76 can be estimated from their annual catches and data on effort-per-unit-catch (EPC) for Japanese trawlers, that is, the hours of fishing per ton of groundfish caught (Appendix Table 1B). Fishing effort by Soviet herring trawlers during 1963-76 can be directly estimated from catch and EPC data provided by the U.S.S.R. (Appendix Table 1C). Since 1977, 1976, 1977, 1979, and 1980, in that order, the U.S.S.R., Republic of Korea, Taiwan, Poland, and West Germany have reported the number of hours fished annually by their respective trawlers (Appendix Table 1A). Fishing effort by United States trawlers engaged in domestic and joint venture groundfish fisheries in the region since 1980 can be estimated from catches reported for those fisheries and EPC data for foreign trawlers combined (Appendix Table 1D).

Total annual trawl fishing effort for groundfish, shrimp, and herring during 1963-83, as reported or estimated for foreign and U.S. vessels in the Bering Sea-Aleutian Islands region, is given in Table 1 and shown in Figure 2. Effort was about 340,000 and 400,000 h in 1963 and 1964, respectively, but decreased to about 250,000 h in 1965 and 1966, mainly because of sharp drops in flatfish and herring catches by Soviet vessels. Effort then rebounded as the pollock fishery developed during the late 1960's and peaked at approximately 500,000 h in the early 1970's. Since then it has fluctuated around a level of about 450,000 h annually.

Effort by U.S. trawlers has accounted for an increasing fraction of the total effort in recent years, from 3% in 1980 to 18% in 1983, displacing more and more of the foreign effort.

Table 1.--Trawl fishing effort for groundfish, shrimp, and herring by foreign and United States fisheries in the Bering Sea-Aleutians region, 1963-83 (thousands of hours). Data sources: Japan, Republic of Korea, Taiwan, West Germany, and Poland - Appendix Table 1A; the U.S.S.R. groundfish 1963-76, Appendix Table 1B; herring 1963-76, Appendix Table 1C; groundfish and herring combined, 1977-83, Appendix Table 1A; and United States Appendix Table 1D.

	Japan		U.S.S.R.		Republic of Korea	Taiwan	West Germany	Poland	Total foreign nations	United States	
Year	Groundfish and herring	Shrimp	Groundfish	Herring	Groundfish					Domestic and joint venture	All nations
1963	172	--	75	90	--	--	--	--	337	--	337
1964	203	--	90	105	--	--	--	--	398	--	398
1965	168	23	55	--	--	--	--	--	246	--	246
1966	182	18	44	--	--	--	--	--	244	--	244
1967	262	2	63	--	--	--	--	--	327	--	327
1968	301	7	44	13	--	--	--	--	365	--	365
1969	310	2	54	50	--	--	--	--	416	--	416
1970	369	4	58	76	--	--	--	--	507	--	507
1971	390	4	86	27	--	--	--	--	507	--	507
1972	402	--	87	13	--	--	--	--	502	--	502
1973	341	--	68	9	--	--	--	--	418	--	418
1974	374	--	107	12	--	--	--	--	493	--	493
1975	357	--	93	9	--	--	--	--	459	--	459
1976	354	+	82	10	56	--	--	--	502	--	502
1977	371	+	27		8	1	--	--	407	--	407
1978	380	--	53		17	2	--	--	452	--	452
1979	367	--	33		26	1	--	5	432	--	432
1980	391	--	1		38	2	2	13	447	13	460
1981	364	--	--		30	4	3	12	413	30	443
1982	358	--	--		29	6	3	--	396	45	441
1983	330	--	--		32	--	--	--	363	82	444

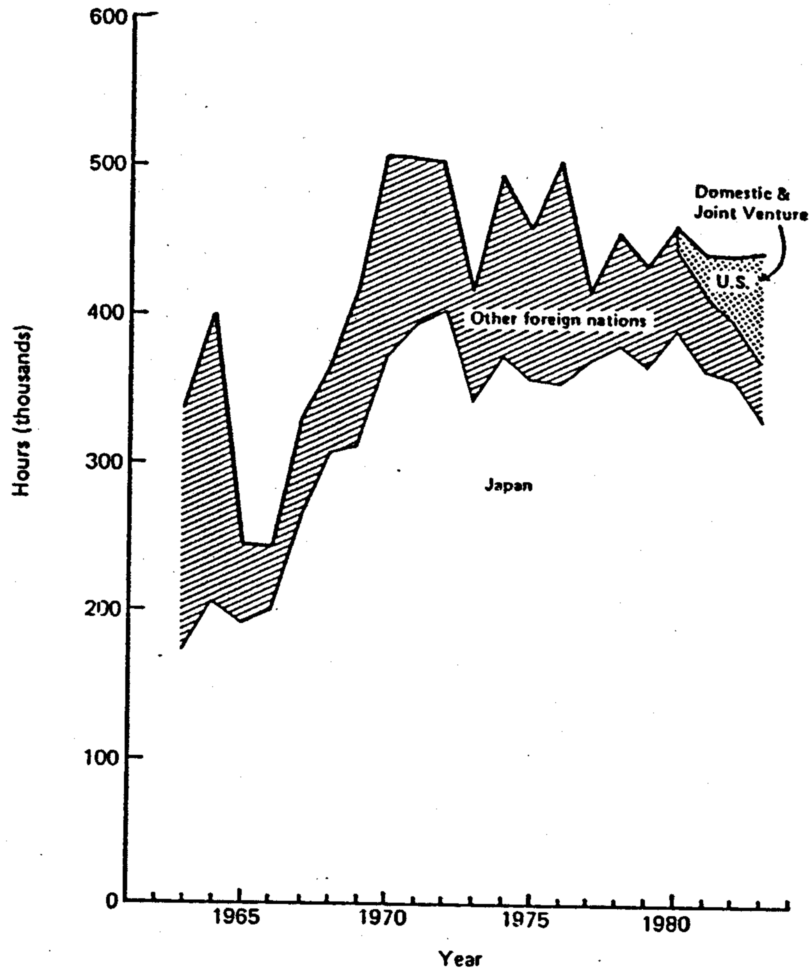

Figure 2.--Trawl fishing effort for groundfish shrimp and herring by foreign and U.S. fisheries in the Bering Sea-Aleutians region, 1963-83.

Pre-1963 fishing effort by Japanese and Soviet trawl fisheries for groundfish can be estimated by multiplying annual catches (text table, above) by 0.5, the average EPC for groundfish caught by Japanese trawlers during 1963-67, years when the average annual Japanese-Soviet catch was about the same as it was in 1962 (Appendix Table 1B). Similarly, herring trawl effort by Soviet vessels during 1959-62 can be estimated by multiplying their annual catches of herring by 0.6, the average EPC during 1968-73 (Appendix Table 1C). Resulting estimates of annual effort during 1954-62 are as follows:

Estimates of annual trawl fishing effort (1,000 h)

	Groundfish		Herring	
Year	Japan	U.S.S.R.	U.S.S.R.	Total
1954	6	--	--	6
1955	8	--	--	8
1956	12	--	--	12
1957	12	--	--	12
1958	23	2	--	25
1959	80	31	6	117
1960	218	48	6	272
1961	266	77	48	391
1962	238	70	90	398

As indicated previously by catch data, there was a rapid buildup of trawl effort beginning in 1959. By 1961, it reached the level of the early peak (1963-64) shown in Figure 2.

The areal distribution of trawl fishing effort since 1963, as indicated by data from the Northwest and Alaska Fisheries Center, National Marine Fisheries Service (NWAFC data file) for Japanese fisheries, which accounted for approximately three-fourths of the total trawl effort in the region during 1963-83, has been as follows:

		Percent effort by area			
Years	Average annual effort (1,000 h)	1	2	3+4	5
1963-69	236	39	45	10	6
1970-76	370	24	56	14	6
1977-83	367	29	53	+	18

Effort shifted from Area 1 to Area 2 in the early 1970's as the pollock fishery developed, and the closure of the U.S.S.R. 200-mile zone in 1977 led to a shift in effort from Areas 3 and 4 to Area 5 (the Aleutians area).

The distribution of Japanese fishing effort by vessel type (Appendix Table 1A) has been as follows:

Percent of average annual effort by vessel type

Years	Pair trawl	Side trawl-fish	Stern trawl-fish	Danish seine	Side trawl-shrimp	Stern trawl-shrimp
1963-69	6	12	20	59	3	+
1970-76	11	+	63	25	+	+
1977-83	8	0	83	9	+	+

Danish seiners and side trawlers fishing for groundfish accounted for most of the fishing effort through most of the 1960's, but stern trawlers have since become the predominant type of vessel used in the region. They presently account for about 85% of the total annual effort.

Herring Gill Net Fishery - Japan

The Japanese herring gill net fishery in the Bering Sea peaked in the mid-1960's (Table 2 and Fig. 3), when practically all of the fishing effort was in Areas 3 and 4, near the U.S.S.R. coast. During the 1970's, practically all of the fishing was done east of long. 170°W (Area 1). At its peak in 1965, cumulative total effort during the year represented about 37,000 km of gill net (one tan being a 46-m length of gill net). The fishery was terminated in 1980.

Crab Tangle Net Fishery - Japan

Japan's crab tangle net fishery in the southeastern Bering Sea began in 1953 and terminated in 1973. Peak effort (Table 2 and Fig. 4) was in 1963-64, representing a cumulative total of about 26,000 km of tangle nets set during a season, one tan being a 40-m length of net in this fishery.

NORTHEAST PACIFIC REGION

Foreign and Joint Venture Groundfish Trawl Fisheries

Foreign trawling for groundfish began in the northeastern Pacific region (Fig. 5) in 1962, when Soviet trawlers initiated a fishery for rockfish in the Gulf of Alaska. Japan started fishing in 1963. In 1966, both nations extended their fishing operations to waters off British Columbia, Washington, and Oregon, Soviet vessels accounting for most of the effort by a wide margin. The Republic of Korea and Poland began fishing in the region in the early 1970's, and Canadian and United States vessels initiated joint venture fisheries with other nations in 1978.

Japan has reported the number of hours fished annually by vessels in its groundfish trawl fishery in the region since 1963, and the U.S.S.R., Republic of Korea, and Poland since 1977 (Appendix Table 2A). Effort in the Gulf of Alaska by trawlers of the latter three nations prior to 1977 can be estimated from their catches and EPC data for Japanese stern trawlers (Appendix Table 2B). Effort by Soviet trawlers off British

Table 2.--Gill net fishing effort for herring in the Bering Sea, 1963-79, and tangle net fishing effort for crabs in the southeastern Bering Sea, 1953-72 (in thousands of tans). Data sources: herring, 1963-70 - International North Pacific Fisheries Commission (INPFC) Bulletin 37; 1971-79: - INPFC Statistical Yearbooks; crabs - INPFC Statistical Yearbooks.

	Japan	
Year	Herring gill net fishery	Crab tangle net fishery
1953	--	106
1954	--	61
1955	--	99
1956	--	147
1957	--	84
1958	--	99
1959	--	78
1960	--	93
1961	NA	292
1962	NA	438
1963	225	642
1964	454	639
1965	816	452
1966	503	447
1967	556	440
1968	404	485
1969	174	272
1970	84	252
1971	134	28
1972	122	12
1973	131	Fishery terminated
1974	96	
1975	46	
1976	128	--
1977	53	--
1978	--	--
1979	9	--
1980	Fishery terminated	--

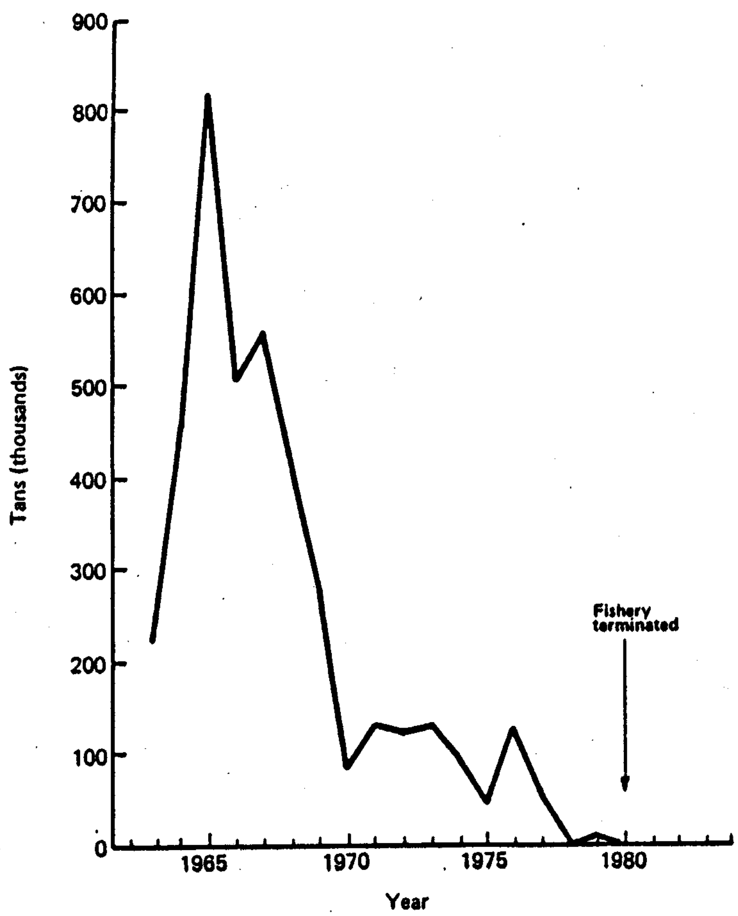

Figure 3.--Gill net fishing effort for herring by Japan in the Bering Sea, 1963-83.

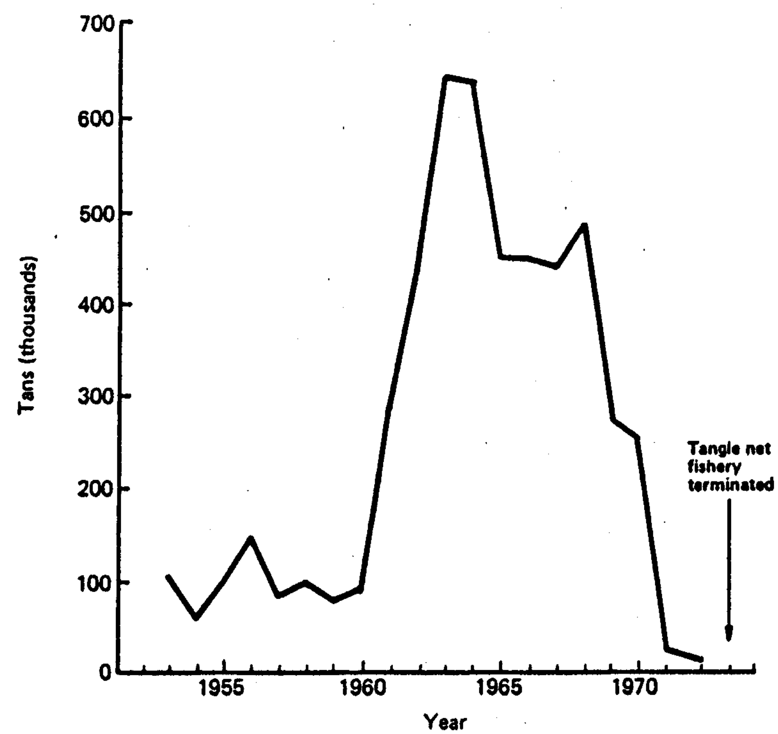

Figure 4.--Tangle net fishing effort for crabs by Japan in the southeastern Bering Sea, 1953-72.

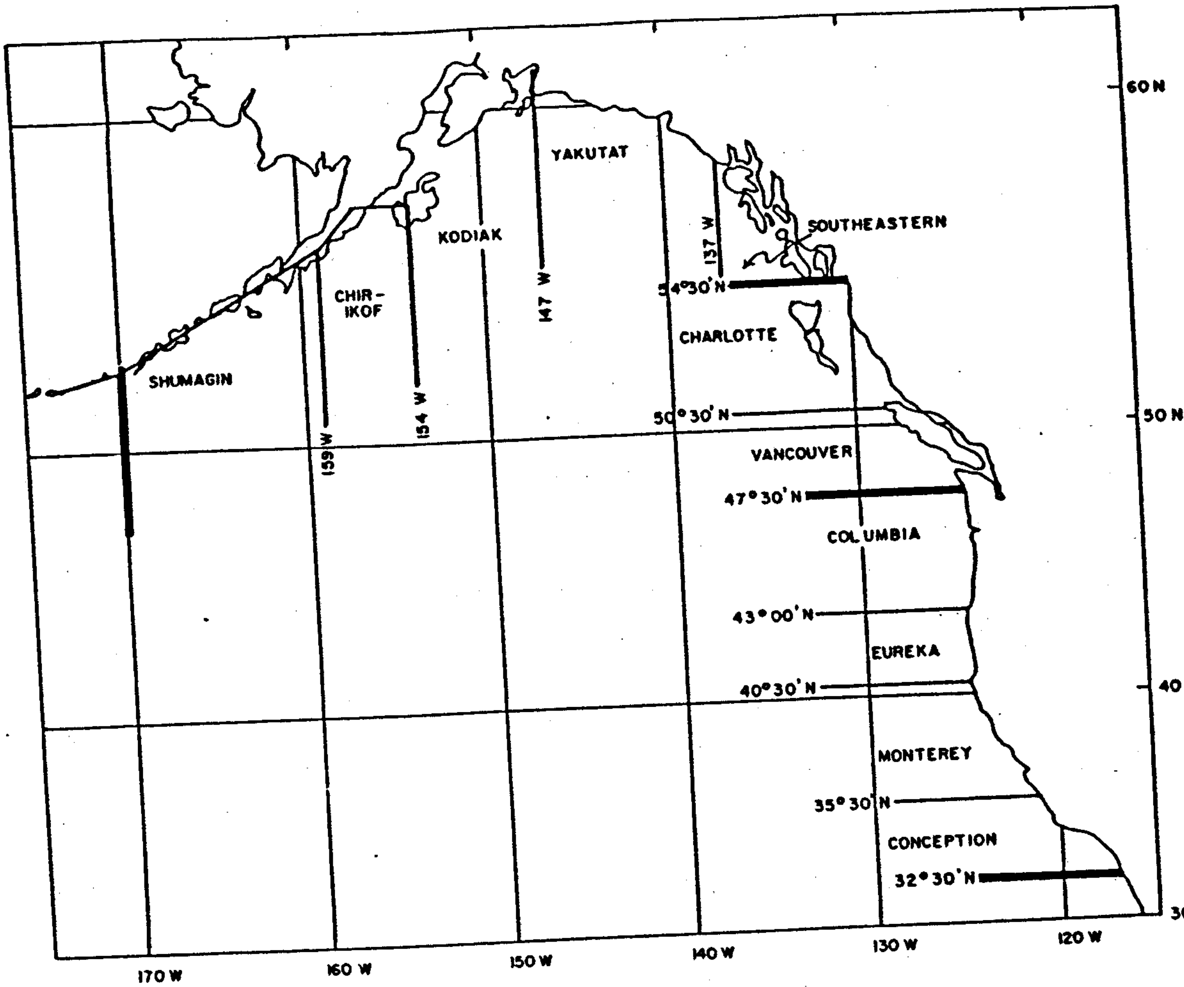

Figure 5.--The northeast Pacific region as defined by the International North Pacific Fisheries Commission and its areal divisions.

Columbia in 1966, when they targeted on rockfish, can be similarly estimated (Appendix Table 2C). Trawl effort by the U.S.S.R. and Poland off British Columbia during 1967-76 and off Washington-Oregon-California during 1966-76 can be estimated from the catches of hake by the two nations and EPC data for the Soviet hake trawl fishery (Appendix Tables 2C and 2D). Effort by Canadian and United States trawlers involved in joint venture fisheries in different sectors of the region since 1978 can be estimated from their groundfish catches and EPC data for the combined trawl fisheries of Japan, U.S.S.R., the Republic of Korea, and Poland (Appendix Table 2E).

Total annual trawl effort for groundfish by foreign and joint venture fisheries in the northeast Pacific region during 1962-83, as reported or estimated and excluding a relatively minor amount of effort by Japanese Danish seiners, side trawlers, and shrimp trawlers in the mid-1960's, is given in Table 3 and shown in Figure 6.

Effort increased from slightly less than 15,000 h in 1962 to nearly 170,000 h in 1967, decreased to the 100,000 h level during the next 5

Table 3.--Trawl fishing effort for groundfish in the northeast Pacific region by Japanese, U.S.S.R., Republic of Korea, Polish, Canadian joint venture and United States joint venture fisheries, 1962 to 1983, in thousands of hours (INPFC = International North Pacific Fisheries Commission). Data sources: Japan 1963-83 - Appendix Table 2A. U.S.S.R. 1962-76 - Appendix Tables 2B, 2C, 2D; 1977-78 - Appendix Table 2A. Republic of Korea 1972-75 - Appendix Table 2B; 1976-83 - Appendix Table 2A. Poland 1973-76 - Appendix Tables 2B, 2C, 2D; 1977-83 - Appendix Table 2A. Canada and United States joint ventures - Appendix Table 2E.

		Foreign					Joint venture			
Area	Year	Japan	U.S.S.R.	Republic of Korea	Poland	Total	Canada	United States	Total	Total
Gulf of Alaska	1962	--	13	--	--	13	--	--	--	13
INPFC areas	1963	2	27	--	--	29	--	--	--	29
Shumagin to	1964	3	35	--	--	38	--	--	--	38
southeastern	1965	8	51	--	--	59	--	--	--	59
	1966	13	12	--	--	25	--	--	--	25
	1967	14	15	--	--	29	--	--	--	29
	1968	16	13	--	--	29	--	--	--	29
	1969	24	6	--	--	30	--	--	--	30
	1970	15	2	--	--	17	--	--	--	17
	1971	19	9	--	--	28	--	--	--	28
	1972	29	24	1	--	54	--	--	--	54
	1973	37	24	2	--	63	--	--	--	63
	1974	36	31	1	--	68	--	--	--	68
	1975	39	52	6	1	98	--	--	--	98
	1976	35	40	7	--	82	--	--	--	82
	1977	34	15	5	+	54	--	--	--	54
	1978	28	14	5	1	48	--	+	+	48
	1979	23	7	5	4	39	--	+	+	39
	1980	32	17	4	3	56	--	1	1	57
	1981	36	--	8	8	52	--	5	5	57
	1982	29	--	6	--	35	--	22	22	57
	1983	29	--	3	--	32	--	39	39	71
British	1962	--	--	--	--	--	--	--	--	--
Columbia[1]	1963	--	--	--	--	--	--	--	--	--
INPFC areas:	1964	--	--	--	--	--	--	--	--	--
Charlotte	1965	--	--	--	--	--	--	--	--	--
and	1966	1	6	--	--	7	--	--	--	7
Vancouver	1967	5	6	--	--	11	--	--	--	11
	1968	5	19	--	--	24	--	--	--	24
	1969	4	25	--	--	29	--	--	--	29
	1970	3	12	--	--	15	--	--	--	15
	1971	2	3	--	--	5	--	--	--	5
	1972	4	2	--	--	6	--	--	--	6
	1973	3	8	--	--	11	--	--	--	11
	1974	7	1	--	--	8	--	--	--	8
	1975	4	2	--	8	14	--	--	--	14
	1976	3	2	--	1	6	--	--	--	6
	1977	3	--	--	1	4	--	--	--	4
	1978	+	--	--	+	+	+	--	+	+
	1979	1	--	--	1	2	1	--	1	3
	1980	1	--	--	2	3	5	--	5	8
	1981	+	--	--	1	1	7	--	7	8
	1982	1	--	--	--	1	5	--	5	6
	1983	--	--	--	--	--	7	--	7	7
Washington-	1962	--	--	--	--	--	--	--	--	--
Oregon-	1963	--	--	--	--	--	--	--	--	--
California	1964	--	--	--	--	--	--	--	--	--
INPFC areas:	1965	--	--	--	--	--	--	--	--	--

Table 3.--Continued.

Area	Year	Foreign: Japan	Foreign: U.S.S.R.	Foreign: Republic of Korea	Foreign: Poland	Foreign: Total	Joint venture: Canada	Joint venture: United States	Joint venture: Total	Total
Columbia to Conception	1966	+	83	--	--	83	--	--	--	83
	1967	2	126	--	--	128	--	--	--	128
	1968	1	40	--	--	41	--	--	--	41
	1969	+	55	--	--	55	--	--	--	55
	1970	+	65	--	--	65	--	--	--	65
	1971	1	65	--	--	66	--	--	--	66
	1972	1	43	--	--	44	--	--	--	44
	1973	2	51	--	1	54	--	--	--	54
	1974	4	62	--	18	84	--	--	--	84
	1975	3	51	--	14	68	--	--	--	68
	1976	3	51	--	8	62	--	--	--	62
	1977	--	26	--	4	30	--	--	--	30
	1978	--	19	--	5	24	--	+	+	24
	1979	--	31	--	5	36	--	3	3	39
	1980	--	--	--	12	12	--	7	7	19
	1981	--	--	--	20	20	--	14	14	34
	1982	--	--	--	--	--	--	19	19	19
	1983	--	--	--	--	--	--	20	20	20
Total: northeast Pacific region	1962	--	13	--	--	13	--	--	--	13
	1963	2	27	--	--	29	--	--	--	29
	1964	3	35	--	--	38	--	--	--	38
	1965	8	51	--	--	59	--	--	--	59
	1966	14	101	--	--	115	--	--	--	115
	1967	21	147	--	--	168	--	--	--	168
	1968	22	72	--	--	94	--	--	--	94
	1969	28	86	--	--	114	--	--	--	114
	1970	18	79	--	--	97	--	--	--	97
	1971	22	77	--	--	99	--	--	--	99
	1972	34	69	1	--	104	--	--	--	104
	1973	42	83	2	1	128	--	--	--	128
	1974	47	94	1	18	160	--	--	--	160
	1975	46	105	6	23	180	--	--	--	180
	1976	41	93	7	9	150	--	--	--	150
	1977	37	41	5	5	88	--	--	--	88
	1978	28	33	5	6	72	+	+	+	72
	1979	24	38	5	10	77	1	3	4	81
	1980	33	17	4	17	71	5	8	13	84
	1981	36	--	8	29	73	7	19	26	99
	1982	30	--	6	--	36	5	41	46	82
	1983	29	--	3	--	32	7	59	65	98

[1]Including waters off the United States southern boundary of the Vancouver area is lat. 47°30'N and the northern boundary of the Charlotte area is lat. 54°30'N.

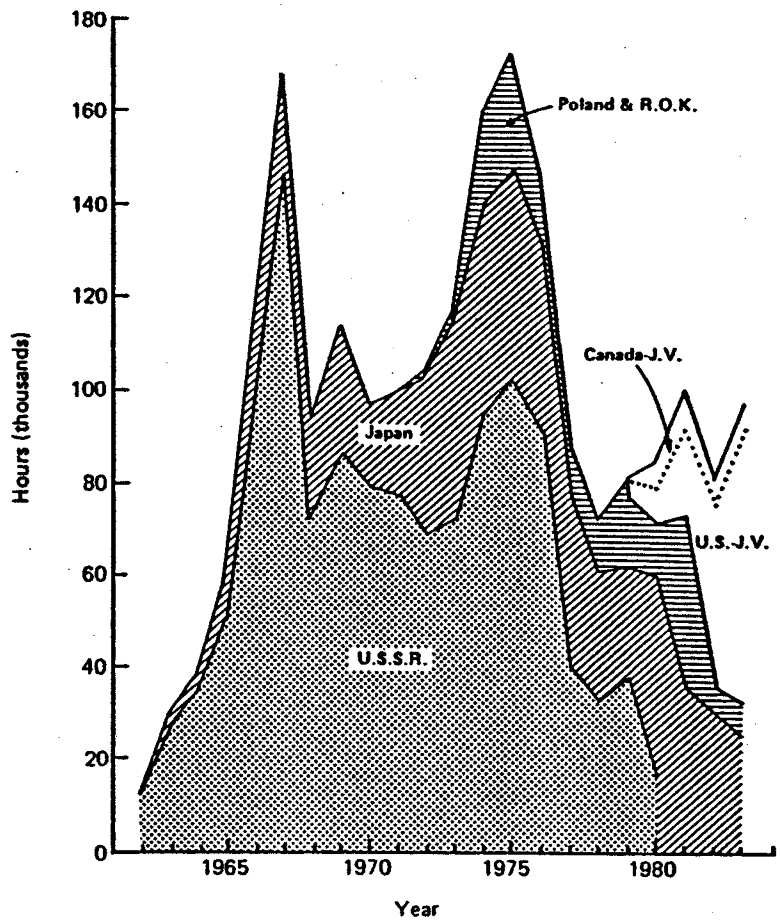

Figure 6.--Trawl fishing effort for groundfish in the northeast Pacific region by Japanese, U.S.S.R., Republic of Korea, Polish, Canadian joint venture and United States joint venture fisheries 1962-83.

years, and built up again to 180,000 h in 1975. It then dropped to about 70,000 h by 1978 and has since fluctuated between 80,000 and 100,000 h annually. Current level of effort is about 55% of the 1974-76 level.

Foreign trawl effort has declined markedly in the region as a whole since Canada and the United States established 200-mile fisheries jurisdiction zones. Effort by vessels engaged in joint venture fisheries has offset a substantial portion of the reduction in foreign fishing.

Trends in trawl fishing effort by foreign and joint venture vessels have varied in different sectors of the northeast Pacific region (Fig. 7). In the Gulf of Alaska, the overall trend in effort has been upward, although the current level of effort is less than it was in 1975-76. Off British Columbia, effort peaked at nearly 30,000 h in 1969 and then declined over the next 10 years. It has held at about 7,000 h in recent years (through 1983). Off Washington-Oregon-California, the overall trend in effort has been downward. Effort in 1983 was less than one-third of

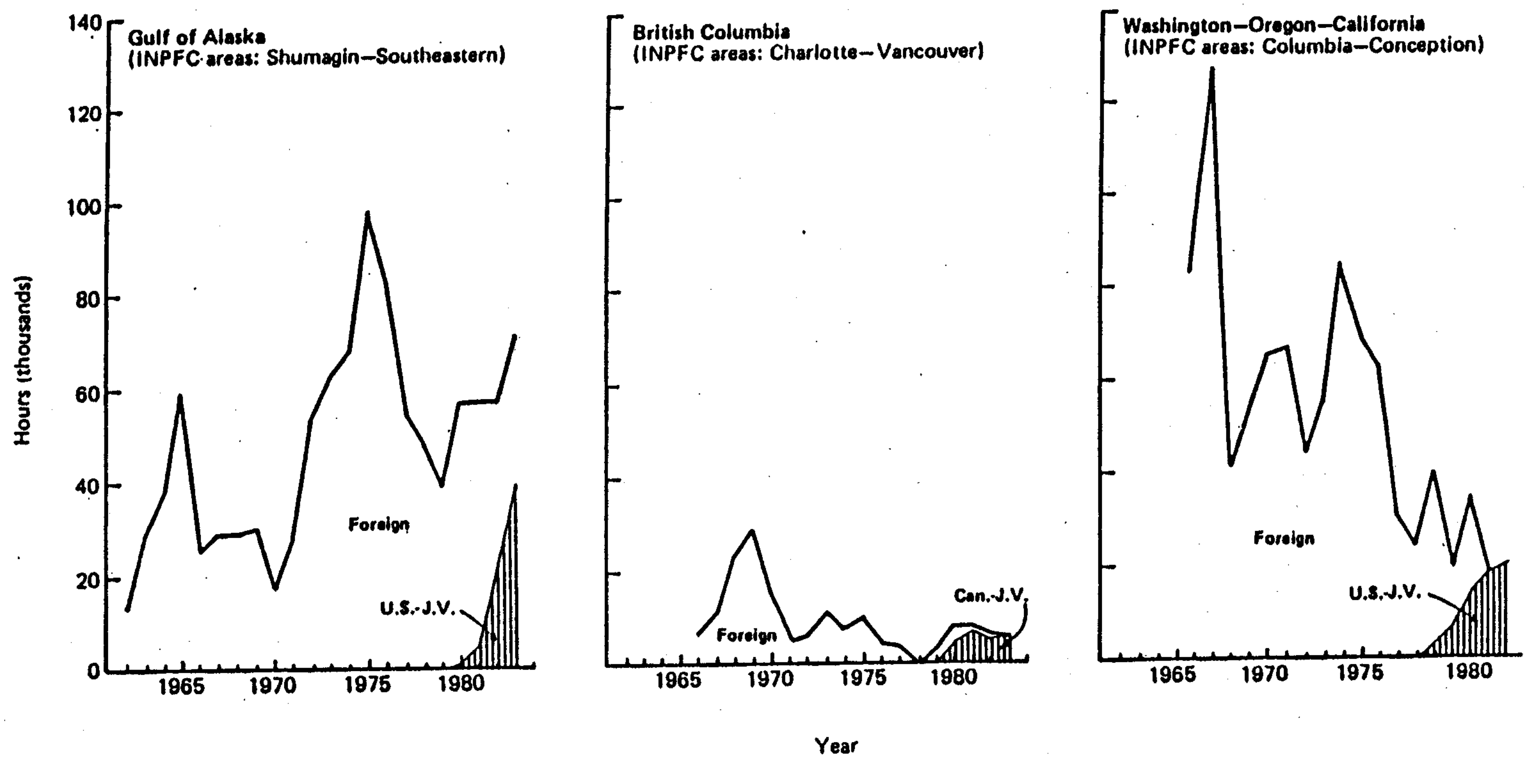

Figure 7.--Trawl fishing effort for groundfish in different sectors of the northeast Pacific region by foreign and joint venture fisheries, 1962-83.

the mid-1970's level and only one-sixth of the 1967 peak. Effort in joint venture fisheries in the Gulf of Alaska and off Washington-Oregon-California has increased markedly in the past 3 years.

Domestic Groundfish Trawl Fisheries - Canada and United States

Long before the advent of foreign and joint venture trawl fishing operations in the northwest Pacific region, Canada and the United States had domestic trawl fisheries for groundfish off British Columbia and Washington-Oregon-California. Annual effort by the domestic fisheries during 1956-83, as reported in publications of the International North Pacific Fisheries Commission (INPFC) or estimated in Appendix Table 3, is given in Table 4 and shown in Figure 8.

Total annual effort by the United States and Canadian domestic trawl fisheries for groundfish off British Columbia has been fairly stable since 1956. Effort off Washington-Oregon-California by the United States domestic trawl fishery also was fairly stable for about 15 years (1956-71), but it has since more than doubled.

JAPANESE HIGH SEAS SALMON GILL NET FISHERIES

Mother Ship Salmon Gill Net Fishery

Japan's post-World War II mother ship salmon gill net fishery began in 1952. Area of operation during 1959-76 is shown in Figure 9. Prior to 1959, some mother ship fleets operated west of long. 160°E in the North Pacific Ocean and in the Okhotsk Sea. In 1977, the U.S.S.R. 200-mile zone was closed to high seas salmon fishing, and in 1978 waters east of long. 175°E and south of lat. 56°N were also closed.

Annual fishing effort during 1952-82 in the area depicted in Figure 9 is given in Table 5 and shown in Figure 10. Effort is expressed in the cumulative number of tans of drift gill net fished each year, one tan representing 50 m of net.

Peak effort was in 1956, at close to 9 million tans. It declined over the next 20 years to about 6 million tans in 1976. Areal closures in 1977 and 1978 resulted in cutting the level of effort to about 3 million tans, all west of long. 175°E or north of lat. 56°N.

Land-Based Salmon Drift Net Fishery

Japan's land-based salmon, drift net fishery also began in 1952. Area of operation before and after the closure of waters east of long. 175°E in 1978 is shown in Figure 9.

Data on annual fishing effort by large vessels in the fishery, which are licensed to fish throughout the land-based drift net area (the smaller vessels being restricted to waters west of long. 149°E) and account for approximately 85% of the total catch, are available for 1962 and 1972-82 (Table 6 and Fig. 11).

Table 4.--Trawl fishing effort for groundfish by Canadian and United States domestic fisheries in the northeast Pacific region, 1956 to 1983, in thousands of hours. Data sources: Canada, 1956-70 - International North Pacific Fisheries Commission (INPFC) Bulletin 37; 1971-80 - INPFC Statistical Yearbooks; 1981 - Northwest and Alaska Fisheries Center (NWAFC) data file; 1982 - Leaman 1983; 1983 - Assumed same as in 1982. United States, 1956-61 - Appendix Table 3; 1962 - INPFC Bulletin 37; 1963 - Charlotte and Vancouver areas - Appendix Table 3; Columbia-Conception areas - INPFC Bulletin 37; 1964-70 - INPFC Bulletin 37; 1971-75 - INPFC Statistical Yearbooks; 1976 and 1979: Charlotte-Columbia areas - INPFC Statistical Yearbooks; Eureka-Conception areas - Appendix Table 3; 1977-78 and 1980 - INPFC Statistical Yearbooks; 1981 - Charlotte-Columbia Areas - NWAFC data file; Eureka-Conception Areas - Appendix Table 3; 1982-83: Appendix Table 3.

	INPFC Areas						
	Charlotte and Vancouver			Columbia-Conception	Total by nation		
Year	Canada	United States	Total	United States	Canada	United States	Total
1956	31	46	77	78	31	124	155
1957	26	41	67	83	26	124	150
1958	23	41	64	78	23	119	142
1959	22	49	71	74	22	123	145
1960	26	41	67	75	26	116	142
1961	23	40	63	74	23	114	137
1962	25	54	79	87	25	141	166
1963	23	48	71	72	23	120	143
1964	28	54	82	81	28	135	163
1965	29	50	79	87	29	137	166
1966	28	51	79	77	28	128	156
1967	26	46	72	71	26	117	143
1968	29	48	77	71	29	119	148
1969	33	53	86	74	33	127	160
1970	29	45	74	79	29	124	153
1971	31	41	72	85	31	126	157
1972	28	39	67	100	28	139	167
1973	24	37	61	106	24	143	167
1974	24	42	66	105	24	147	171
1975	34	44	78	122	34	166	200
1976	36	48	84	106	36	154	190
1977	35	47	82	112	35	159	194
1978	33	48	81	137	33	185	218
1979	38	52	90	148	38	200	238
1980	47	46	93	161	47	207	254
1981	39	46	85	179	39	225	264
1982	35	38	73	199	35	237	272
1983	35	39	74	174	35	213	248

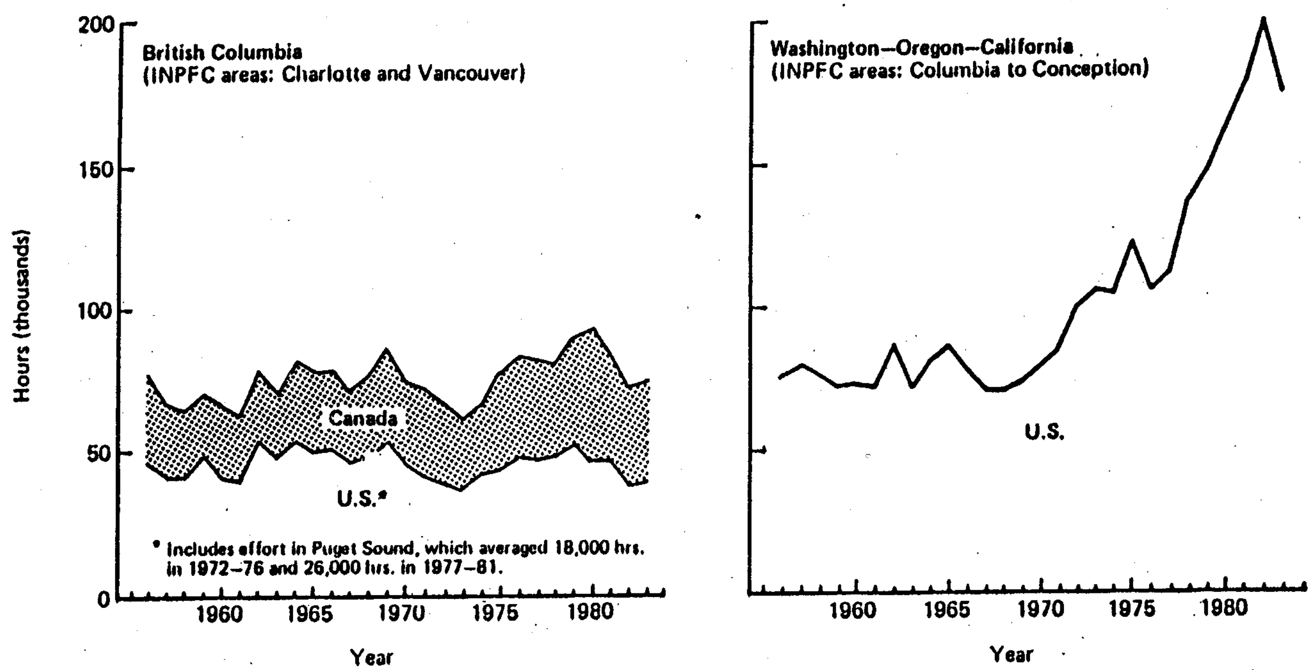

Figure 8.--Trawl fishing effort by Canadian and United States domestic fisheries in the British Columbia and Washington-Oregon-California sectors of the northeast Pacific region, 1956-83.

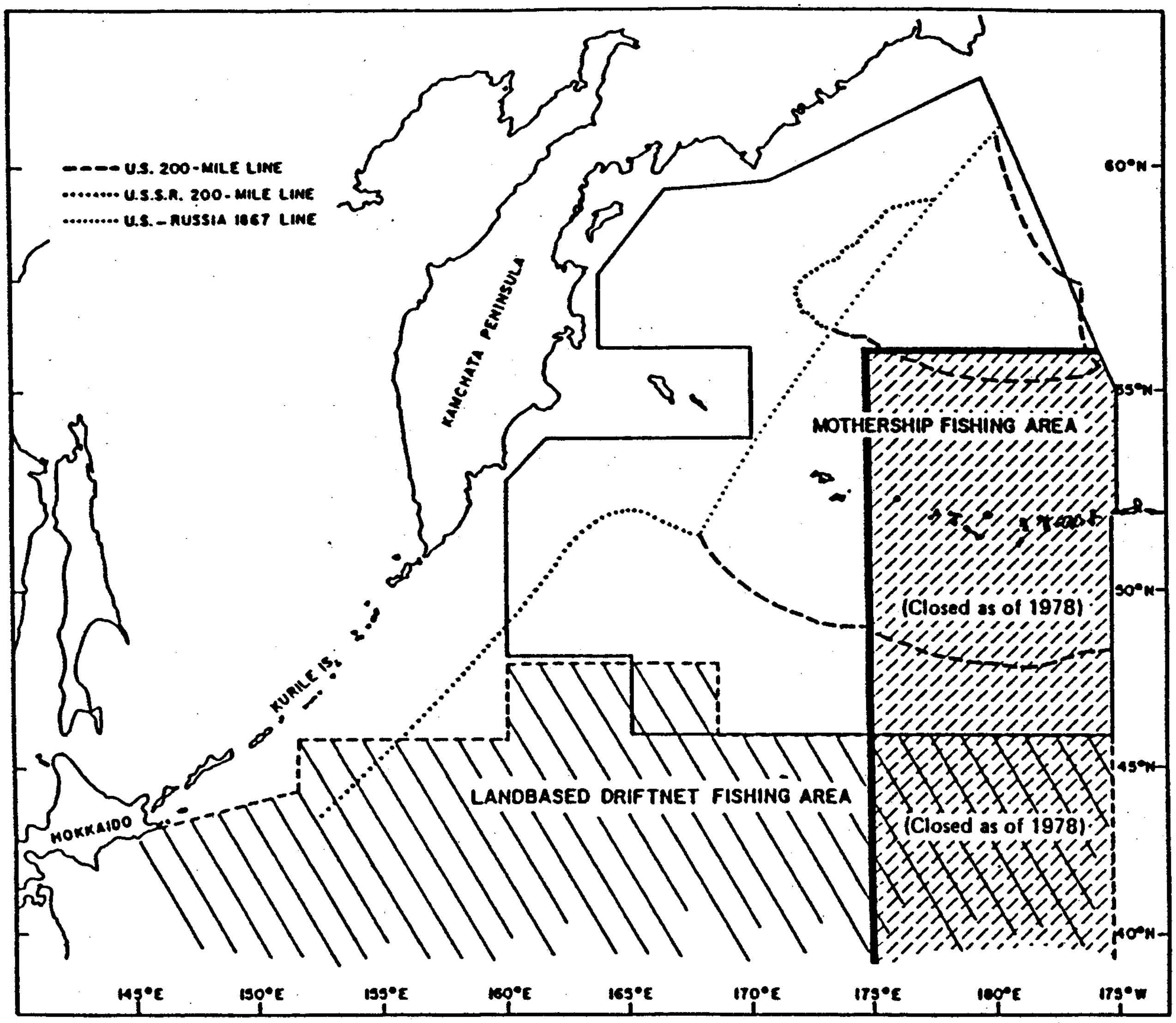

Figure 9.--Japanese high seas salmon gill net fishing areas.

Table 5.--Gill net fishing effort by the Japanese salmon mother ship fishery in the North Pacific Ocean, 1952 to 1982, in thousands of tans. Data sources: 1952-59 - Manzer et al. 1965; 1960-80 - International North Pacific Fisheries Commission (INPFC) Statistical Yearbooks; 1981-82 - Northwest and Alaska Fisheries Center data file.

Year	West of long. 175°E	East of long. 175°E			Total
		South of lat. 56°N	North of lat. 56°N	Total	
1952	311	160	--	160	471
1953	1,124	221	--	221	1,345
1954	3,225	83	--	83	3,308
1955	6,944	46	--	46	6,990
1956	6,377	2,215	137	2,352	8,729
1957	5,134	654	425	1,079	6,213
1958	7,098	16	--	16	7,114
1959	6,607	218	271	489	7,096
1960	4,842	1,029	646	1,675	6,517
1961	3,496	1,473	24	1,497	4,993
1962	5,285	565	--	565	5,850
1963	5,051	535	367	902	5,953
1964	5,016	1,483	1,021	2,504	7,520
1965	3,564	1,707	840	2,547	6,111
1966	3,785	952	459	1,411	5,196
1967	4,165	626	443	1,069	5,231
1968	4,118	788	1,020	1,808	5,926
1969	3,241	2,013	964	2,977	6,218
1970	1,943	2,332	1,754	4,986	6,029
1971	3,261	1,160	1,418	2,578	5,839
1972	3,391	639	1,889	2,528	5,919
1973	3,852	1,534	462	1,996	5,948
1974	2,870	1,885	680	2,565	5,435
1975	3,081	1,903	652	2,555	5,636
1976	3,030	1,973	808	2,781	5,811
1977	1,753	1,367	862	2,229	3,982
1978	2,562	--	158	158	2,720
1979	2,459	--	338	338	2,797
1980	2,604	--	543	543	3,147
1981	2,512	--	390	390	2,902
1982	2,451	--	485	485	2,936

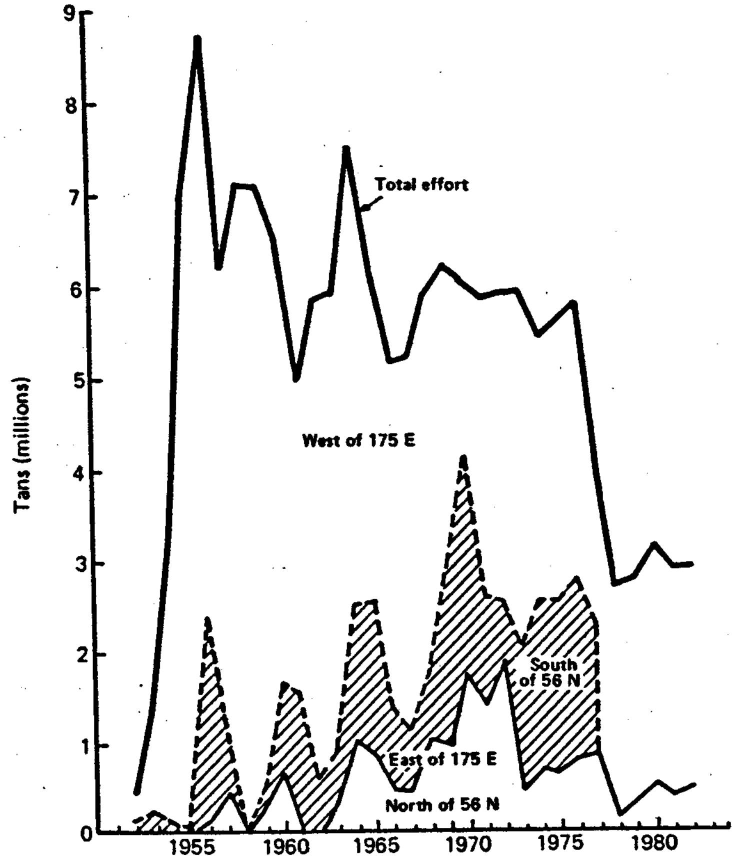

Figure 10.--Gill net fishing effort for salmon by the Japanese mother ship salmon fishery in the North Pacific Ocean, 1953-82.

Table 6.--Gill net fishing effort by large vessels of the Japanese land-based salmon fishery in the North Pacific Ocean, 1962 and 1972-82, in thousands of tans. Data sources: 1962 - International North Pacific Fisheries Commission (INPFC) Circular Letter, 21 October 1963; 1972-74 - Fisheries Agency of Japan (pers. commun.); 1975-76 - INPFC Sec.; 1977 - Fisheries Agency of Japan (pers. commun.); 1978-82 - Northwest and Alaska Fisheries Center data file.

Year	West of long. 175°E	East of long. 175°E	Total
1962	6,865	--	6,865
1963-71		Data not available	
1972	3,331	1,825	5,156
1973	4,583	1,169	5,752
1974	5,226	794	6,019
1975	4,933	1,057	5,990
1976	5,436	511	5,947
1977	3,186	533	3,719
1978	3,372	--	3,372
1979	3,219	--	3,219
1980	3,144	--	3,144
1981	3,234	--	3,234
1982	2,962	--	2,962

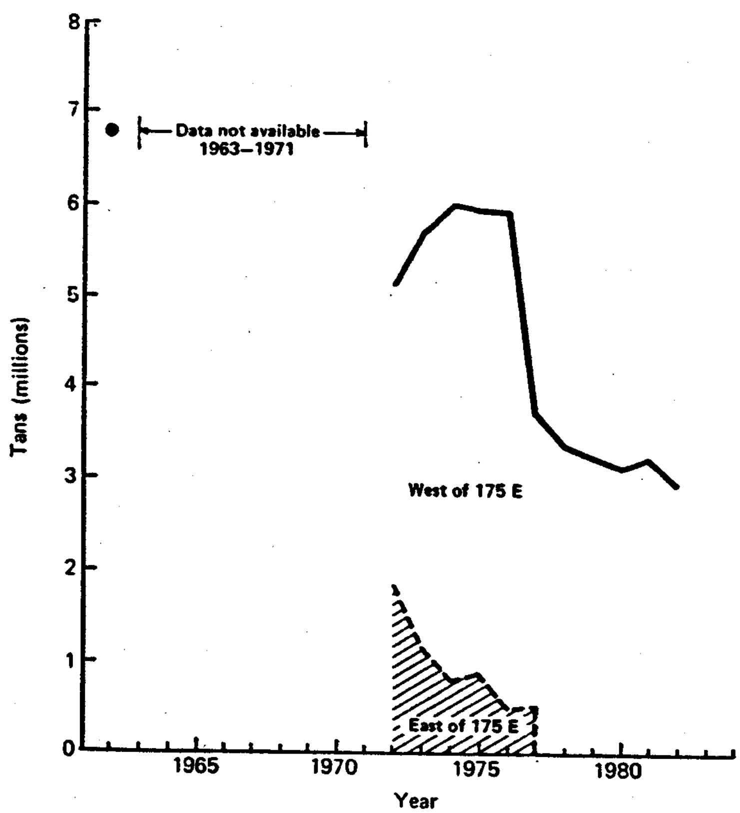

Figure 11.--Gill net fishing effort for salmon by the Japanese land-based salmon fishery in the North Pacific Ocean, 1962 and 1972-82.

The limited effort data for the land-based salmon drift net fishery point to a reduction in effort over the years similar in scale and timing of the reduction in effort for the mother ship salmon fishery.

OTHER HIGH SEAS GILL NET FISHERIES

Several new and major drift gill net fisheries have developed in the central and western North Pacific Ocean within the past decade or so. These include drift net fisheries by Japan, Republic of Korea, and Taiwan for squid and a Japanese drift net fishery for marlin and other species. Information on the amount of fishing effort generated by these fisheries is contained in documents submitted by T. Chen, Y. Gong, and K. Shima for the Workshop on the Fate and Impact of Marine Debris, held in Honolulu, Hawaii, in November 1984.

SUMMARY

Fishing by foreign trawlers in the Bering Sea-Aleutian Islands region began in 1954, but it was largely exploratory in nature and limited in scale until late in the 1950's. Between then and the early 1970's, there was a severalfold increase in fishing effort. During the past 10-12 years, the amount of effort has remained near the high level of the early 1970's, with effort by U. S. vessels engaged in domestic and joint venture fisheries accounting for an increasing fraction of the total effort in recent years.

In the northeast Pacific region, foreign trawlers began fishing for groundfish in 1962. Fishing effort by those vessels increased greatly in the mid-1960's, declined somewhat for a few years in the late 1960's, and then rose to a record high in 1975. It has since fallen off sharply, but fishing effort by United States vessels in joint venture fisheries, and to some extent by Canadian vessels engaged in similar fisheries off British Columbia, has offset a substantial portion of the reduction in foreign fishing. Current level of effort by the combined foreign and joint venture fisheries is about 55% of the 1974-76 peak reached by foreign trawlers.

Effort by Canadian and United States vessels in domestic trawl fisheries for groundfish from northern Washington to Dixon Entrance (INPFC's Charlotte and Vancouver areas) has been relatively stable since 1956. Farther south off the coast of Washington and off Oregon and California, the U.S. domestic trawl effort for groundfish also was fairly stable during 1956-71, but it has more than doubled since then.

Total trawl effort for (a) foreign, domestic, and joint venture fisheries in the Bering Sea-Aleutian Islands region and (b) United States and Canadian domestic trawl fisheries for groundfish from British Columbia to California has more than tripled since 1956. Estimates of annual average effort (third text table and Tables 1, 3, and 4) are as follows:

Years	Average annual effort (1,000 h)
1956-60	234
1961-65	537
1966-70	641
1971-75	782
1976-80	764
1981-83	794

Fishing effort by the Japanese mother ship salmon fishery, a high seas drift gill net fishery in the Bering Sea and central-western North Pacific Ocean, currently is about half of what it was during 1960-76 and an even smaller fraction of the level of effort in the late 1950's. Limited data for the Japanese land-based drift net fishery, another high seas net fishery for salmon in the North Pacific Ocean, point to a similar reduction in fishing effort by that fishery. There has been no high seas gill net fishery for salmon in the U.S.S.R. 200-mile zone since 1977, or east of long. 175°E, or south of lat. 56°N, since 1978.

Japan's tangle net fishery for crabs in southeastern Bering Sea was terminated in 1973, after 20 years of operation, and Japan's herring gill net fishery in the Bering Sea terminated in 1980. Peak effort for both fisheries had been in the mid-1960's.

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Appendix Table 1A.--Trawl fishing effort reported for foreign fisheries in the Bering Sea-Aleutians region, 1963-83, in number of hours (from the Northwest and Alaska Fisheries Center data file).

	Japanese fisheries								Other foreign trawl fisheries				
	Groundfish and herring					Shrimp			Groundfish				
Year	Pair trawl	Side trawl	Stern trawl	Danish seine[1]	Total	Side trawl	Stern trawl	Total	U.S.S.R.	Republic of Korea	Taiwan	West Germany	Poland
1963	15,646	33,115	0	123,218	171,979	0	0	0					
1964	11,799	40,003	1,884	148,958	202,644	0	0	0					
1965	6,960	30,410	4,043	126,856	168,269	23,163	0	23,163					
1966	11,800	39,817	6,345	123,970	181,932	17,543	0	17,543					
1967	20,626	32,421	48,719	160,616	262,382	1,730	206	1,936					
1968	15,242	9,756	130,623	145,852	301,473	4,666	2,105	6,771					
1969	13,889	10,241	137,459	148,438	310,027	0	2,094	2,094	See Appendix Table 1B		No fishing		
1970	31,262	4,958	166,199	166,128	368,547	48	4,433	4,481					
1971	42,868	2,989	219,012	124,660	389,529	44	4,413	4,457					
1972	46,322	1,734	248,854	104,896	401,806	0	0	0					
1973	46,961	0	197,649	96,708	341,318	0	0	0					
1974	46,931	0	261,634	65,222	373,787	0	0	0					
1975	42,337	0	268,284	46,334	356,955	0	0	0					
1976	39,651	0	273,830	40,220	353,701	0	347	347		55,640			
1977	35,727	0	296,797	38,500	371,024	0	244	244	26,811	7,782	1,280		
1978	32,254	0	312,723	34,842	379,819	0	0	0	53,395	17,495	1,699		
1979	33,004	0	299,908	34,422	367,334	0	0	0	32,726	26,323	1,014		4,643
1980	34,737	0	319,250	37,074	391,061	0	0	0	651	38,176	2,104	1,718	13,105
1981	29,272	0	303,183	31,092	363,547	126	0	126	0	29,536	3,694	3,469	12,115
1982	28,595	0	305,396	24,296	358,287	0	0	0	0	29,083	6,321	3,094	0
1983	24,167	0	285,029	21,114	330,310	0	0	0	0	31,579	0	0	0

[1]Hours fished by Danish seiners is estimated from number of drags reported at 2 h per drag.

Appendix Table 1B.--Estimates of U.S.S.R. trawl fishing effort for groundfish in the Bering Sea-Aleutians region, 1963-78, in number of hours (MT = metric tons).

	Japan			U.S.S.R.	
	Trawlers (fish net) and Danish seiners--groundfish and herring			Trawlers--groundfish	
Year	Effort (hours)[1]	Catch (MT)[2]	Hours per ton	Catch (MT)[3]	Estimated effort (hours)[4]
1963	171,979	211,581	0.8128	92,000	74,778
1964	202,644	350,663	0.5779	155,000	89,574
1965	168,269	350,561	0.4800	115,000	55,200
1966	181,932	414,521	0.4389	100,000	43,890
1967	262,382	747,052	0.3512	177,662	62,395
1968	301,473	916,979	0.3288	133,975	44,051
1969	310,027	1,072,132	0.2892	186,700	53,994
1970	368,547	1,477,219	0.2495	231,881	57,854
1971	389,529	1,802,880	0.2161	397,477	85,894
1972	401,806	1,913,897	0.2099	412,896	86,667
1973	341,318	1,752,331	0.1948	347,969	67,784
1974	373,787	1,526,183	0.2449	435,052	106,544
1975	356,955	1,299,261	0.2747	338,417	92,963
1976	353,701	1,210,629	0.2922	279,697	81,727

[1]From Appendix Table 1A.

[2]From International North Pacific Fisheries Commission (INPFC) Bulletin 37 and INPFC Statistical Yearbooks. Groundfish catch by pair trawl, side trawl (fish net), stern trawl (fish net), and Danish seines.

[3]From INPFC Bulletin 37 (Table 1) for 1963 and from Murai et al. (1981) for 1964-76.

[4]Hours per ton for Japanese vessels times U.S.S.R. catch.

Appendix Table 1C.--Estimates of U.S.S.R. trawl fishing effort for herring in eastern Bering Sea, 1963-76, in number of hours (MT = metric tons).

Year	Catch (MT)[1]	No. of tows[2]	No. of hours at 3.4 h/tow[3]	Hours per ton	Effort (hours)[4]
1963	150,000	NA	--	[5](0.6)	(90,000)
1964	175,000	NA	--	[5](0.6)	(105,000)
1965	--	--	--	--	--
1966	--	--	--	--	--
1967	--	--	--	--	--
1968	22,255	3,885	13,209	0.5935	13,209
1969	94,491	14,762	50,191	0.5312	50,191
1970	117,202	22,236	75,602	0.6451	75,602
1971	23,000	8,008	27,227	1.1838	27,227
1972	54,000	3,805	12,937	0.2396	12,937
1973	34,361	2,536	8,876	0.2583	8,876
1974	19,800	NA	--	[5](0.6)	(11,880)
1975	14,206	NA	--	[5](0.6)	(8,523)
1976	16,812	NA	--	[5](0.6)	(10,087)

[1]From Murai et al. (1981).

[2]From catch and catch per unit effort data (by vessel class) provided by U.S.S.R. during United States and U.S.S.R. fisheries meetings.

[3]From data provided by U.S.S.R. for 1974 for eastern Bering Sea. (Average hours per tow for three vessels classes: BMRT-7; SRTM-6; and SRTR-6.)

[4]Catch times hours per ton.

[5]Rounded average of 1968-73 data.

Appendix Table 1D.--Estimates of trawl fishing effort for groundfish by the U.S. domestic and joint venture fisheries in the Bering Sea-Aleutians region, 1980-83, in number of hours.

	1980	1981	1982	1983
Estimated number of hours of trawling by foreign nations, incuding Danish seine drags (Japan) converted to hours at 2 h per drag (from Appendix Table 1A)	446,815	412,487	396,785	361,889
Foreign catch of groundfish by trawlers (from R. Nelson, Northwest and Alaska Fisheries Center (with longline catch subtracted)) (pers. commun.)	1,282,114	1,258,347	1,178,050	1,111,003
U.S. trawl catch of groundfish				
Domestic landings	5,858	14,187	24,800	41,368
Joint venture landings	32,668	78,535	108,603	211,155
Total	38,526	92,722	133,403	252,523
(from R. Nelson pers. commun.)				
Hours per ton of catch for foreign trawlers (1 ÷ 2)	0.3485	0.3278	0.3368	0.3257
Estimated equivalent number of hours trawled by U.S. vessels in the domestic and joint venture fisheries (4 x 3)	13,426	30.394	44,930	82,247
Estimated total hours of trawling by U.S. and foreign vessels for groundfish (1 + 5).	460,241	442,881	441,715	444,136

Appendix Table 2A.--Trawl fishing effort for groundfish as reported for foreign nations in the northeast Pacific region, 1963-83, in number of hours. (Canadian vessels and Japanese and Danish seiners and shrimp trawlers excluded.) Data sources: Japan 1963-70 from the International North Pacific Fisheries Commission (INPFC) Bulletin 37; 1971-80 from the INPFC Statistical Yearbooks. All other data are from the Northwest and Alaska Fisheries Center data file.

	Gulf of Alaska Shumagin-southeastern areas				British Columbia Charlotte-Vancouver areas			Washington-Oregon-California Columbia-Conception areas		
Year	Japan	U.S.S.R.	Republic of Korea	Poland	Japan	U.S.S.R.	Poland	Japan	U.S.S.R.	Poland
1963	2,275	(1)	(2)	(2)	0	0	0	0	0	0
1964	2,507	(1)	(2)	(2)	0	0	0	0	0	0
1965	7,789	(1)	(2)	(2)	0	0	0	0	0	0
1966	12,560	(1)	(2)	(2)	923	(3)	0	92	(4)	0
1967	13,925	(1)	(2)	(2)	4,564	(3)	0	1,823	(4)	0
1968	16,042	(1)	(2)	(2)	5,457	(3)	0	803	(4)	0
1969	23,789	(1)	(2)	(2)	3,829	(3)	0	236	(4)	0
1970	14,704	(1)	(2)	(2)	2,641	(3)	0	210	(4)	0
1971	18,808	(1)	(2)	(2)	2,141	(3)	0	599	(4)	0
1972	29,013	(1)	(1)	(2)	4,377	(3)	0	1,142	(4)	0
1973	37,297	(1)	(1)	(2)	3,306	(3)	0	2,414	(4)	(4)
1974	36,342	(1)	(1)	(2)	7,056	(3)	0	3,925	(4)	(4)
1975	38,894	(1)	(1)	(1)	4,190	(3)	(3)	2,678	(4)	(4)
1976	34,715	(1)	6,523	0	3,226	(3)	(3)	2,667	(4)	(4)
1977	33,651	14,967	4,797	374	2,716	0	1,484	0	26,036	3,785
1978	27,842	14,317	5,315	702	362	0	141	0	19,473	5,415
1979	22,884	7,360	4,869	3,917	556	0	848	0	31,448	5,209
1980	31,694	17,247	3,901	2,663	502	0	1,556	0	0	12,302
1981	36,195	0	8,499	8,223	298	0	1,183	0	0	19,796
1982	29,080	0	6,406	0	581	0	0	0	0	0
1983	28,665	0	3,162	0	0	0	0	0	0	0

[1]See Appendix Table 2B.
[2]No fishing.
[3]See Appendix Table 2C.
[4]See Appendix Table 2D.

Table 2B.--Estimates of trawl fishing effort for groundfish by the U.S.S.R., Republic of Korea, and Poland in the Gulf of Alaska (Shumagin-southeastern areas), 1962-76, in number of hours (MT = metric tons). (Estimates are based on catch rates by Japanese trawlers.)

Year	Japanese trawlers			Catch (MT)[1]			Estimated effort (hours)[2]		
	Effort (hours)[3]	Catch (MT)[4]	Hours per ton	U.S.S.R.	Republic of Korea	Poland	U.S.S.R.	Republic of Korea	Poland
1962	--	--	--	50,000	--	--	[5](12,655)	--	--
1963	2,275	8,989	0.2531	108,000	--	--	27,335	--	--
1964	2,507	16,347	0.1534	230,000	--	--	35,282	--	--
1965	7,789	51,512	0.1512	340,000	--	--	51,408	--	--
1966	12,560	84,004	0.1495	83,000	--	--	12,408	--	--
1967	13,925	72,852	0.1911	76,937	--	--	14,703	--	--
1968	16,042	72,518	0.2212	59,422	--	--	13,145	--	--
1969	23,789	82,521	0.2883	20,015	--	--	5,770	--	--
1970	14,704	64,429	0.2282	9,336	--	--	2,130	--	--
1971	18,808	66,259	0.2839	30,719	--	--	8,721	--	--
1972	29,013	84,851	0.3419	68,864	4,042	--	23,545	1,382	--
1973	37,297	91,402	0.4081	59,522	4,332	--	24,291	1,768	--
1974	36,342	90,715	0.4006	77,942	2,237	--	31,224	896	--
1975	38,894	70,851	0.5490	95,465	11,800	2,132	52,410	6,478	1,170
1976	34,715	69,678	0.4982	79,873	34,348	--	39,793	(3)	--

[1]From Pruter (1976) for 1962-63; from Murai et al. (1981) for 1964-76.
[2]Hours per ton for Japanese trawlers times catch by indicated nation.
[3]From Appendix Table 2A.
[4]From International North Pacific Fur Commission (INPFC) Bulletin 37 and INPFC Statistical Yearbooks.
[5]Hours per ton for Japanese trawlers in 1963 times U.S.S.R. catch in 1962.

Appendix Table 2C.--Estimates of trawl fishing effort for groundfish by the U.S.S.R. and Poland off British Columbia (Charlotte-Vancouver areas), 1966-76, in number of hours (MT = metric tons). (Except for 1966, estimates are derived from data for the U.S.S.R. hake fishery.)

	U.S.S.R.				Poland	
Year	Hake catch (MT)[1]	No. of tows[2]	Effort (hours)[3]	Hours per ton	Hake catch (MT)	Estimated effort (hours)
1966	0	NA	[4](5,861)	--	0	0
1967	11,260	2,458	6,145	0.5457	0	0
1968	35,804	7,708	19,270	0.5382	0	0
1969	52,792	10,050	25,125	0.4759	0	0
1970	25,491	4,701	11,752	0.4610	0	0
1971	5,021	1,028	2,570	0.5119	0	0
1972	5,816	931	2,328	0.4003	0	0
1973	13,840	3,101	7,752	0.5601	0	0
1974	1,799	403	1,003	0.5575	0	0
1975	3,493	NA	(1,768)	[5](0.5063)	15,704	(7,951)
1976	3,918	NA	(1,983)	[5](0.5063)	2,054	(1,040)

[1]From Murai et al. (1981). No hake catch in 1966, but total groundfish catch of 33,000 MT.

[2]From catch and catch per unit effort data (by vessel class) provided by U.S.S.R. during United States and U.S.S.R. fisheries meetings.

[3]At 2.5 h per tow as derived from data for 1974 for British Columbia, Washington, Oregon, and California.

[4]Hours per metric tons for Japanese trawlers (923 h per 5,198 MT, or 0.1776) times 33,000 MT (U.S.S.R. groundfish catch).

[5]Average for 1967-74; used to estimate effort.

Appendix Table 2D.--Estimates of trawl fishing effort for groundfish by the U.S.S.R. and Poland off Washington-Oregon-California (Columbia-Conception areas) in the northeast Pacific region, 1966-76, in number of hours (MT = metric tons). (Estimates are derived from data for the U.S.S.R. hake fishery.)

	U.S.S.R.				Poland	
Year	Hake catch (MT)[1]	No. of tows[2]	Effort (hours)[3]	Hours per ton	Hake catch (MT)[1]	Estimated effort (hours)[4]
1966	128,000	NA	[5](82,432)	--	0	0
1967	195,092	50,346	125,636	0.6440	0	0
1968	67,896	16,054	40,135	0.5911	0	0
1969	109,225	21,893	54,733	0.5011	0	0
1970	200,754	25,825	64,562	0.3216	0	0
1971	146,726	26,157	65,392	0.4457	0	0
1972	111,269	17,277	43,192	0.3882	0	0
1973	139,060	20,566	51,415	0.3697	2,220	821
1974	156,708	24,725	62,175	0.3968	44,354	17,600
1975	155,405	NA	[6](51,066)	[7](0.3286)	41,542	13,650
1976	154,129	NA	[7](50,646)	[7](0.3286)	23,668	7,777

[1]From Murai et al. (1981).

[2]From catch and catch per unit effort data provided by U.S.S.R. for 1967-73. Data on number of tows and hours fished in 1974 provided by U.S.S.R.

[3]At 2.5 h per tow, as derived from data provided by U.S.S.R. for 1974.

[4]Catch times hours per ton for U.S.S.R. fishery.

[5]Based on hours per ton for 1967.

[6]Estimated from average hours per ton in 1974 and 1977.

[7]Average for 1974 and 1977. Hours per ton in 1977 derived as follows: Hours fished 26,036; hake catch 99,938; hours per ton 0.2605.

Appendix Table 2E.--Estimates of trawl fishing effort for groundfish by the United States joint venture and Canadian joint venture fisheries in the northeast Pacific region, 1978-83, in number of hours (MT = metric tons).

		Japan-U.S.S.R.-Republic of Korea-Poland combined			United States joint venture		Canada joint venture	
Area	Year	Effort (hours)[1]	Catch (MT)[2]	Hours per ton	Catch (MT)[3]	Estimated effort (hours)[4]	Catch (MT)[5]	Estimated effort (hours)[4]
Gulf of Alaska	1978	48,176	151,468	0.3181	48	15	--	--
Shumagin-	1979	39,030	130,787	0.2984	1,522	454	--	--
southeastern	1980	55,505	163,598	0.3393	1,911	648	--	--
area	1981	52,917	198,942	0.2660	16,966	4,512	--	--
	1982	35,486	121,546	0.2920	74,450	21,739	--	--
	1983	31,827	115,950	0.2745	142,984	39,249	--	--
British Columbia	1978	503	3,952	0.1273	--	--	1,814	231
Charlotte-	1979	1,404	8,310	0.1690	--	--	4,233	715
Vancouver	1980	2,058	5,676	0.3626	--	--	13,210	4,790
areas	1981	1,481	3,840	0.3857	--	--	18,400	7,097
	1982	581	2,421	0.2400	--	--	20,051	4,812
	1983	--	--	[6](0.2569)	--	--	27,715	(7,120)
Washington-	1978	24,888	99,028	0.2513	856	215	--	--
Oregon-	1979	36,657	124,065	0.2955	8,834	2,610	--	--
California	1980	12,302	48,505	0.2536	27,537	6,983	--	--
Columbia-	1981	19,796	61,203	0.3234	43,557	14,086	--	--
Conception	1982	--	--	[7](0.2810)	67,465	(18,958)	--	--
areas	1983	--	--	[7](0.2810)	72,100	(20,260)	--	--

[1]From Appendix Table 2A.
[2]From Northwest and Alaska Fisheries Center (NWAFC) data file.
[3]From Berger et al. (1984)
[4]Catch times hours per ton for Japan, U.S.S.R., Republic of Korea, and Poland.
[5]Data for 1978-80 are from INPFC Statistical Yearbook for 1980. Data for 1981-83 are from Pacific Marine Fisheries Commission Annual Reports for 1982-83.
[6]Average for 1978-82.
[7]Average for 1978-81.

Appendix Table 3.--Trawl fishing effort for groundfish by the U.S. domestic fishery in the Charlotte-Vancouver and Columbia-Conception areas of the northeast Pacific region, 1956-83, as reported or estimated, in number of hours (MT = metric tons). Data sources: Catch: 1956-70, International North Pacific Fisheries Commission (INPFC) Bulletin 37; 1971-80, INPFC Statistical Yearbooks; 1981, Charlotte-Vancouver-Columbia areas, Northwest and Alaska Fisheries Center (NWAFC) data files; 1981, Washington-Oregon-California landings, Pacific Marine Fisheries Commission (PMFC) annual report; 1982-83, Washington-Oregon-California landings PMFC annual reports; effort (reported): 1962-70, INPFC Bulletin 37; 1971-80, INPFC Statistical Yearbooks; 1981, NWAFC data file.

	Charlotte-Vancouver			Columbia-Conception			Columbia only		
Year	Effort (hours)	Catch (MT)	Hours per ton	Effort (hours)	Catch (MT)	Hours per ton	Effort (hours)	Catch (MT)	Hours per ton
1956	(46,489)	21,826	[1]2.13	(78,302)	27,571	[2]2.84	--	--	--
1957	(41,137)	19,313	[1]2.13	(82,894)	29,188	[2]2.84	--	--	--
1958	(41,460)	19,465	[1]2.13	(78,276)	27,562	[2]2.84	--	--	--
1959	(48,743)	22,884	[1]2.13	(73,931)	26,032	[2]2.84	--	--	--
1960	(41,369)	19,422	[1]2.13	(74,985)	26,403	[2]2.84	--	--	--
1961	(40,479)	19,004	[1]2.13	(74,476)	26,224	[2]2.84	--	--	--
1962	53,972	20,504	2.63	86,982	28,727	3.03	35,216	14,405	2.44
1963	(47,612)	22,353	[1]2.13	71,782	29,035	2.47	12,535	13,373	0.91
1964	53,769	19,472	2.76	81,128	27,489	2.95	28,500	13,205	2.16
1965	49,878	24,154	2.06	87,110	30,605	2.85	27,065	14,454	1.87
1966	50,580	30,861	1.64	77,437	28,220	2.74	22,114	11,844	1.87
1967	45,787	28,362	1.61	71,173	31,444	2.26	19,431	16,303	1.19
1968	47,932	27,327	1.75	71,092	23,097	3.08	19,825	7,148	3.08
1969	52,611	26,929	1.95	74,048	25,494	2.90	20,882	7,993	2.61
1970	44,595	22,552	1.98	79,155	26,048	3.04	23,052	7,576	3.04
1971	41,081	19,045	2.16	84,729	28,975	2.92	25,278	9,600	2.63
1972	39,217	19,065	2.06	99,745	35,569	2.80	26,279	8,982	2.93
1973	36,855	18,275	2.02	105,562	36,565	2.89	24,090	8,081	2.98
1974	42,108	19,476	2.16	105,374	40,902	2.58	25,858	9,633	2.68
1975	43,661	17,257	2.53	131,895	38,392	3.18	33,771	10,143	3.33
1976	48,118	19,237	2.49	(105,769)	43,348	[3]2.44	34,851	14,298	2.44
1977	47,319	22,428	2.11	112,503	50,376	2.23	29,431	14,297	2.06
1978	47,612	23,271	2.05	136,904	64,999	2.11	46,740	23,563	1.98
1979	51,923	26,110	1.99	(148,053)	79,173	[3]1.87	72,195	38,693	1.87
1980	46,065	21,948	2.10	160,531	83,703	1.92	58,870	42,010	1.40
1981	46,141	18,565	2.49	(178,505)	88,369	[4]2.02	77,335	29,134	2.65
1982	(38,240)	[5]19,120	[6]2.00	(199,388)	99,694	[6]2.00	--	--	--
1983	(38,990)	[5]19,495	[6]2.00	(173,670)	86,835	[6]2.00	--	--	--

[1]Average for 1962 and 1964-81. Used to estimate total effort.
[2]Average for 1962-75. Used to estimate effort.
[3]Hours per ton for Columbia area. Used because of similarity of rates after 1967.
[4]Average for Columbia area in 1980-81.
[5]50% of Washington landings assumed to have been fish taken in the Vancouver area.
[6]Assumed value.

SUMMARY OF JAPANESE NET FISHERIES IN THE NORTH PACIFIC OCEAN[1]

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Summary of Japanese net fisheries in the North Pacific Ocean

Type of fisheries	Operating area	Operating season	No. of vessels	No. of net setting (/day. vessel) (B)	No. of days engaged (/year. vessel) (C)	No. of operation (/year) (D) =(AxBxC)	No. of net used (/operation) (E)	No. of net used (/year) (F) =(DxE)	Quality of net used
Medium trawl (Hokuten)	Bering Sea	Whole year	70	3	200	42,000	1	42,000	Polyethylene
Medium trawl (Other than Hokuten)	Bering Sea	Whole year	16	3.5	210-290	11,800-16,200	1	11,800-16,200	Polyethylene
Large trawl (North Pacific)	Bering Sea Gulf of Alaska	Whole year	Larger 22 smaller 14	4.5 3	90-260 220-240	8,900-25,700 9,200-10,100	1	8,900-25,700 8,200-10,100	Polyethylene polyester
Mother ship type trawl	Bering Sea	June-Oct.	M. 6 C.B. 84	3	120-150	20,200-25,200	1	20,200-25,200	Polyethylene
Mother ship salmon drift gill net	Northwest	June-July	M. 4 C.B. 172	1	50	8,600	300 (tan)[1]	2,838,000 (tan) 127,710 km	Nylon (monofilament)
Land-based type salmon drift gill net	Northwest Pacific	May-July	209	1	40	8,400	300 (tan)	2,772,000 (tan) 124,740 km	Nylon (monofilament)
Squid drift gill net	North Pacific	June-Dec.	511	1	60	30,700	700 (tan)	21,490,000 (tan) 967,100 km	Nylon (monofilament)
Marlin and others drift gill net	North Pacific	Whole year	East of 170°E 140 West of 170°E 460	1 1	40 30	5,600 13,800	260 (tan) 200 (tan)	1,456,000 (tan) 65,520 km 2,760,000 (tan) 124,200 km	Nylon (multifilament)

[1] 1 tan = 45 m

Note: Average figures are used on this table. The figures of the above columns, (C), (D), and (F) are calculated on the assumption that all vessels operated all days engaged. Therefore, actual figures are lower level than figures in each columns. The number of the catcher boats of mother ship type trawl includes 28 pairs of two-boat type trawls.

[1]The contents of this table were presented orally at the Workshop on the Fate and Impact of Marine Debris. Provisional as of 1983.

In R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. 1985.

HIGH SEA GILL NET FISHERIES OF TAIWAN

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INTRODUCTION

In recent years, Taiwan's gill net fishing industry has developed rapidly. Its production increased from 8,475 metric tons (MT) in 1970 to 53,856 MT in 1982, indicating an average annual increase of 3,782 MT. In 1970, there were 524 gill-netters with a total gross tonnage of 4,917 MT; most vessels were <50 MT. By 1982, the number of gill-netters had increased to 1,284, total gross tonnage of 33,479 MT, but 1,209 vessels were <50 MT and 75 were between 200 and 500 MT.

TYPES OF HIGH SEA GILL NETS

Large Mesh Gill Nets for Marlin and Sailfish

Construction: The gear consists of net, float, and rope, with one piece of net made of synthetic fiber, 340 meshes long and 108 meshes deep. The knots are double trawler knots, with a mesh size of 30 cm for shark, 16 cm for sailfish.

<u>Webbing</u>

Color: blue
Twine size: 210 D/3x6 - 210 D/3x2 for shark
210 D/3x6 - 2x0 D/3x8 for sailfish
Hanging coefficient: 0.55 - 0.60 upper
0.75 - 0.80 lower

<u>Buoy line</u>

Material: Polyethylene (PE) (diameter 11 mm) x 2
One in S twist
One in Z twist

<u>Floats</u>

Number: 4-5 for each piece
Shape: Sphere
Diameter: 0.3 m (1 ft)

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Sink line

Material: Polypropylene (PP) (contains lead line, 8 mm) x 2
One in S twist
One in Z twist

Weight: 150 g/m - 200 g/m (in air)

Squid Gill Nets Used in the Northwestern Pacific Ocean

Webbing (each piece)

Material: Nylon monofilament
Type of knot: Double trawler knot
Color: White-blue or white-green
Diameter of monofilament: 0.5-0.7 mm
Length: 500-900 meshes long
Depth: 60-120 meshes deep
Hanging coefficient: 0.57-0.60 (upper)
0.60-0.64 (lower)
Mesh size: 11.5-9.0 cm

Buoy line

Material: PE (diameter 9 mm) x 2

Float

Number: One by each meter
Shape: Elliptical
Buoy force: 250 g/m

Sink line

Material: PP (contains lead 50 g/m) x 2
One in S twist
One in Z twist

Weight: 140 g/m (in air)

SQUID GILL NET FISHERY

Taiwan started its squid fisheries in 1972 and operated in the Sea of Japan from July to October. When the 200-nmi economic zone was enforced by the Soviet Union and Japan in 1977, the squid fishing vessels began to fish in the northwestern Pacific. At first, automatic squid jigging machines were used, but about 1980, some of the squid fishing vessels changed to gill nets because of their high fishing efficiency and energy economy. Now they are the most important squid fishing gear in Taiwan.

Squid Fishing Vessels

In 1980, only 12 squid fishing vessels used gill nets, but the number of squid gill-netters increased to 101 to 1983. Most of the squid gill-netters were converted from tuna longliners. Only about 17% of the vessels were newly built. The vessels range from 100 to 400 MT and about 50% are over 200 MT.

FISHING GROUNDS

Northwestern Pacific (Fig. 1)

In the northwestern Pacific, the squid fishing season begins in the middle of April and ends in November. But 80 to 90% of total squid catches are made from July to October.

The distribution and composition of squid vary with temperature and some other factors. The fishing grounds are located between lat. 35° and 45°N and long. 152°E and 158°W in water 11°-15°C. The species of squid include Ommastrephes bartrami, Onychoteuthis borealijaponica, and Moroteuthis robusta. Ommastrephes bartrami is the most important species. The mantle length of this species measures 25-40 cm, and the body weight is between 450 and 2,200 g.

Squid fishing vessels operating in the northwestern Pacific and their production:

	Squid jigging		Gill net		Total	
Year	No. of vessels	Production (MT)	No. of vessels	Production (MT)	No. of vessels	Production (MT)
1977	6	880	--	--	6	880
1978	14	2,505	--	--	14	2,505
1979	23	3,385	--	--	23	3,385
1980	27	4,824	12	908	39	5,732
1981	28	4,686	44	10,719	72	15,405
1982	25	5,462	73	19,287	98	24,749
1983	34	9,180	101	14,257	135	23,436

South Pacific

The fishing grounds are about 200 nmi off northeastern Australia. The gill nets are usually set about 10 m below the surface of the water to prevent the propellers of fishing vessels from being entangled with the nets. Eight floats are used when they are set near the surface. Recently, monofilament nets have been used, especially in the marlin and sailfish gill net fishery. Owing to their transparency, good catches are obtained with these nets in spite of hardness of the monofilament.

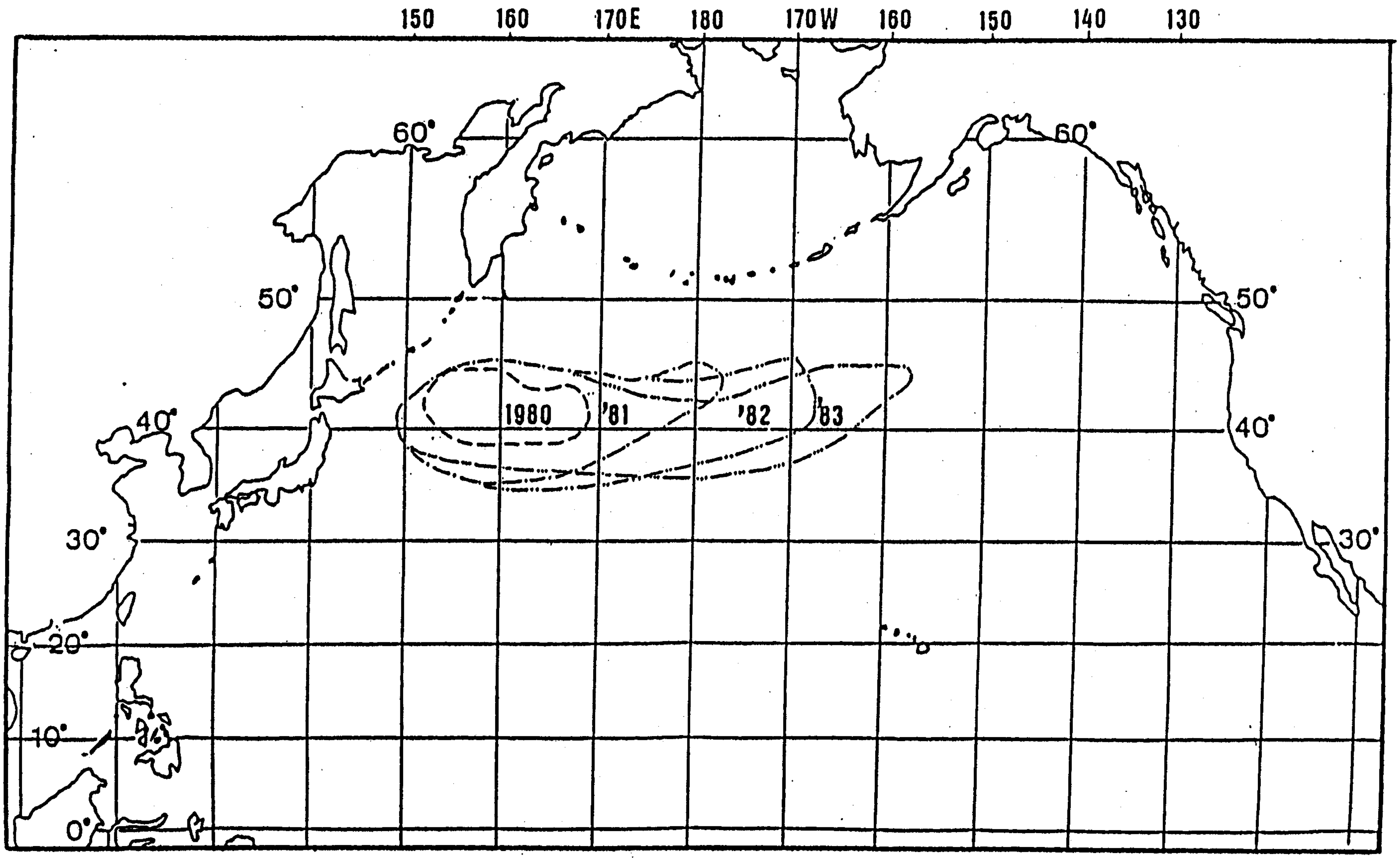

Figure 1.--Taiwan's deep-sea squid fishing ground in northwestern Pacific.